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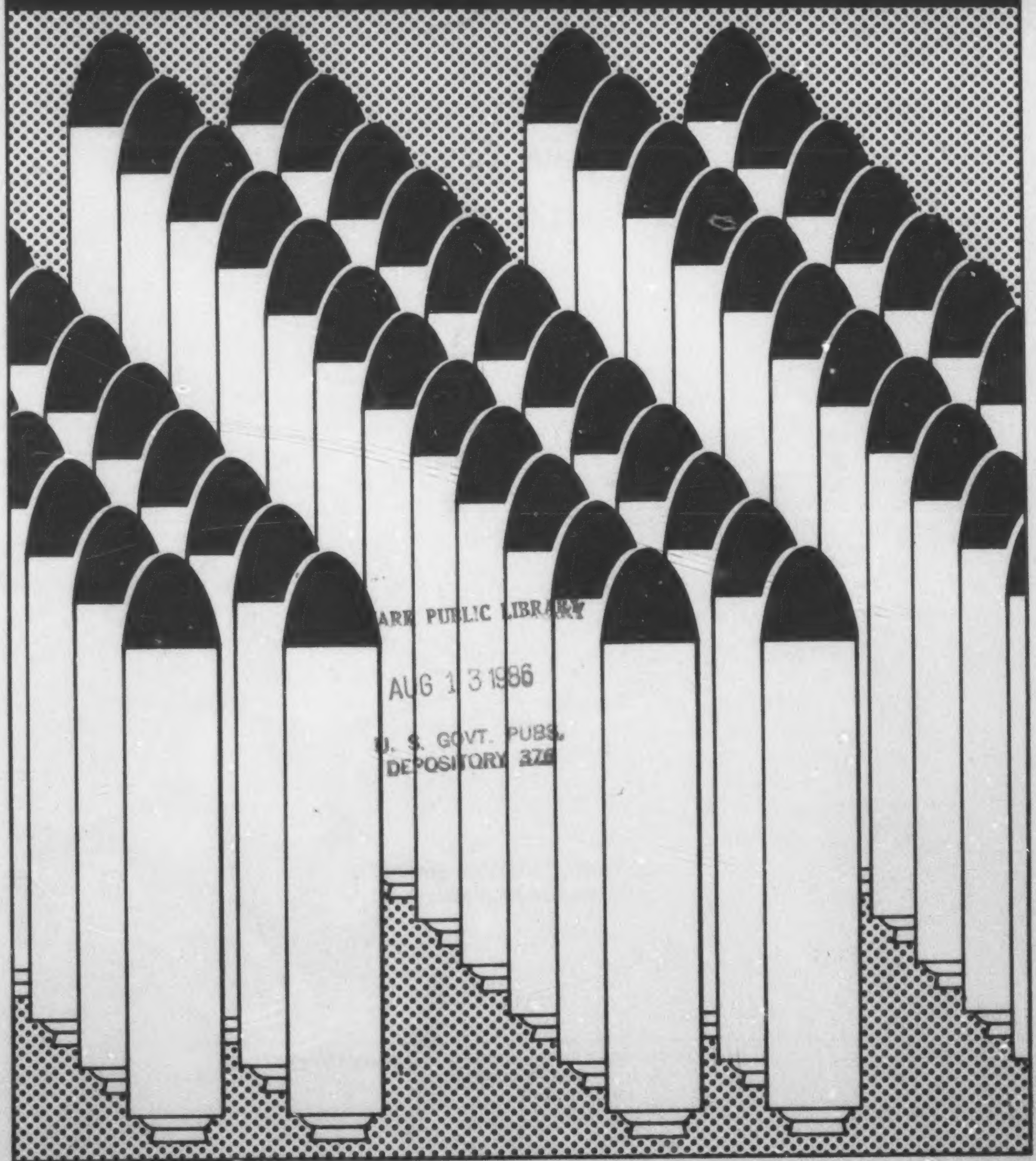
CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

JULY 1986

Trident II Missiles: Capability, Costs, and Alternatives



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TRIDENT II MISSILES:
CAPABILITY, COSTS, AND ALTERNATIVES

The Congress of the United States
Congresssional Budget Office

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NOTES

All years in this report are fiscal years, unless otherwise stated.

Unless otherwise indicated, all budget figures are in fiscal year 1987 dollars.

Figures in the text and tables of this report may not add to totals because of rounding.

Budget figures do not include the cost of procuring ballistic missile warheads. These costs, which are paid by the Department of Energy, are classified.

PREFACE

The Administration is currently modernizing all three legs of the U.S. strategic nuclear triad: bombers, land-based missiles, and submarine-based missiles. As part of this effort, the Administration has asked the Congress to approve initial procurement in fiscal year 1987 of the Trident II missile, which would be deployed aboard Trident submarines.

The Trident II missile, which would be larger, more powerful, and nearly twice as accurate as the Trident I missile that it would replace, would greatly increase U.S. ability to destroy hardened targets in the Soviet Union. This planned increase in U.S. capability has raised concerns about the effect that acquiring the Trident II will have on the ability of the United States to keep a crisis from escalating to nuclear war. Moreover, the costs to achieve this capability are high. This analysis by the Congressional Budget Office (CBO) addresses the costs and capabilities associated with the Administration's program and compares that program with three alternatives. This study was requested by the House Committee on the Budget. In accordance with CBO's mandate to provide objective analysis, the report makes no recommendations.

Jeffrey A. Merkley of CBO's National Security Division prepared the study, under the general supervision of Robert F. Hale and John D. Mayer, Jr. The author thanks Theodore A. Postol of the Center for International Security and Arms Control, Stanford University, for his comments on an earlier draft. (External reviewers bear no responsibility for the final product, which rests solely with CBO.) The author also gratefully acknowledges the contribution of William P. Myers, who assisted with the cost analysis; the contributions of Bonita Dombey, Brad Cohen, and Bertram Braun of CBO's National Security Division; and the assistance of Dorothy Amey, also of CBO. Sherry Snyder, assisted by Nancy H. Brooks, edited the manuscript, and Rebecca J. Kees prepared it for publication.

Rudolph G. Penner
Director

July 1986

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SUMMARY

The United States has deployed three types of strategic nuclear weapons: bombers, land-based missiles, and submarine-based missiles. This triad is designed to deter the Soviet Union from initiating a nuclear war and, if deterrence fails, to enable the United States to employ nuclear weapons in a manner chosen by the U.S. national command authority. All three types of weapons are being modernized. One hundred B-1B bombers are being delivered; air-launched cruise missiles are being deployed on existing B-52 bombers; and development of a new advanced technology or "stealth" bomber continues. Also, the deployment of 50 MX intercontinental ballistic missiles (ICBMs) has been approved. Trident submarines, seven of which have already been deployed and one of which is on sea trials, will continue to replace the older Poseidon submarines.

In addition to these plans, the United States intends to deploy a new submarine-launched ballistic missile (SLBM), the Trident II. The Administration has requested the Congress to fund the first procurement of this missile this year. Its ongoing development and planned procurement is expensive, totaling more than $26 billion between fiscal year 1987 and the year 2000.

The Trident II would eventually replace the Trident I missile on the first eight Trident submarines and would be deployed as original equipment on the subsequent Trident submarines. The greater payload and improved accuracy of the Trident II would enable it to carry larger warheads and deliver them more precisely, making the Trident II very effective in attacking targets, such as Soviet ICBM silos, that have been hardened against nuclear blasts. By the year 2000, approximately 4,800 hard-target warheads would be deployed on Trident II missiles on 20 Trident submarines, resulting in more than a fourfold increase in the number of U.S. hard-target warheads deployed on ballistic missiles.

This planned increase in U.S. hard-target capability would transform the ability of the United States to conduct large-scale attacks on hardened targets in the Soviet Union. The Administration maintains that this change would enhance U.S. deterrence of a Soviet strike. Others counter that the change would have the opposite effect, increasing the probability that a crisis would escalate to nuclear war.

ARGUMENTS FOR AND AGAINST HARD-TARGET CAPABILITY

The ability of U.S. strategic nuclear weapons to survive a Soviet attack and be able to retaliate is the foundation of the U.S. strategy for deterring a nuclear war. Consequently, submarine-launched ballistic missiles are a particularly important part of the U.S. triad of strategic weapons because submarines are less vulnerable to an attack by the Soviet Union than either bombers or missiles based in silos. In addition to being based on submarines, however, the Trident II missile would also have a short flight time to the Soviet Union and the ability to attack and destroy hardened Soviet facilities. These additional features have raised the issue of whether deployment of the Trident II would strengthen or weaken U.S. ability to keep a crisis from escalating to nuclear war.

Proponents of deploying the Trident II and, more generally, expanding U.S. hard-target capability argue that the Trident II would increase U.S. ability to deter a nuclear war. They argue that to deter the Soviet Union from launching a limited nuclear strike against selected U.S. military targets such as missile silos or command centers, the United States must be able to retaliate promptly against diverse sets of Soviet targets that are hardened against nuclear attack. The Trident II missile would provide that capability even after a Soviet attack, since submarines at sea are expected to survive. Increased hard-target capability might also help deter a massive Soviet nuclear attack by enabling the United States to retaliate against critical Soviet facilities such as missile silos and command centers.

Opponents of hard-target capability counter that the Soviet Union would not initiate a limited nuclear strike because the military value of such a strike would not justify the risk that the nuclear war, once initiated by the Soviet attack, would escalate to massive nuclear warfare that would destroy the Soviet Union. Also, deterrence of a massive Soviet attack, argue opponents, is achieved by U.S. capability to retaliate and destroy the Soviet Union as a functioning society, a capability that does not depend on having hard-target warheads. Moreover, expanded U.S. hard-target capability might cause Soviet leaders to prepare to launch their ICBMs on warning of a U.S. attack or to take other actions that increase the probability that a crisis would escalate to nuclear war.

This study cannot resolve the merits of these and many other important arguments for and against hard-target capability. The Administration clearly favors acquiring the capability and plans to do so principally by deploying the Trident II missile. This report analyzes the Administration's plan and alternatives to that plan.

THE ADMINISTRATION'S PLAN

The Administration's plan, as noted above, calls for backfitting the first eight Trident submarines with Trident II missiles and deploying Trident II missiles as original equipment on the ninth and subsequent Trident submarines, building toward a force of 20 submarines.

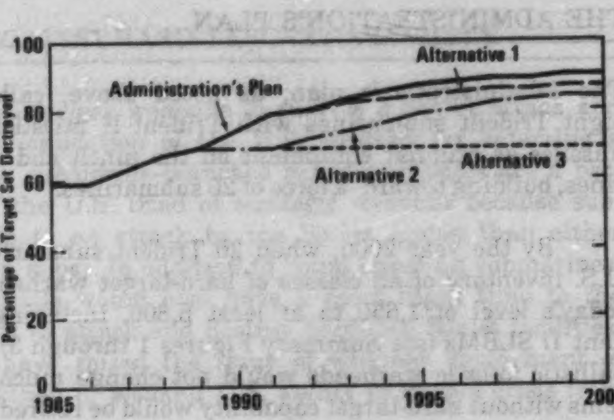
By the year 2000, when 20 Trident submarines would be deployed, the U.S. inventory of all classes of hard-target warheads would have grown from today's level of 1,650 to at least 6,800, including 4,800 warheads on Trident II SLBMs (see Summary Figures 1 through 3). The total number of U.S. ballistic missile warheads would not change much, however, since older systems without hard-target capability would be retired.

This growth in the number of hard-target warheads would greatly increase U.S. ability to destroy both small and large sets of hardened targets in the Soviet Union. The Summary Figures show capability against two hypothetical target sets hardened to 2,000 pounds per square inch (psi)--one large set (2,000 targets) and one small set (500 targets). Assuming that all hard-target warheads on U.S. ballistic missiles--those on submarines as well as land-based missiles--attack the large set, the percentage of targets destroyed would rise under the Administration's plan from 59 percent in 1986 to 90 percent by the year 2000. It may be appropriate, however, to consider only warheads on submarines, since they are thought most likely to survive a Soviet attack. Then the percentage destroyed would rise from about 28 percent in 1986 to over 85 percent by the year 2000. Results are similar if submarine-based warheads attack the small target set, which reflects a more limited U.S. mission or a decision that some targets can be attacked with other weapons such as bombs and air-launched cruise missiles.

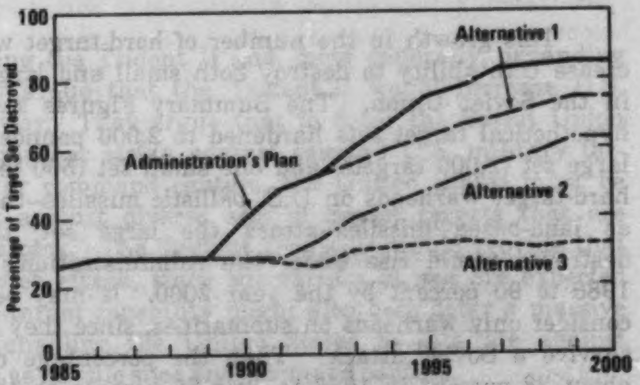
These measures provide a range of estimates of the growth of hard-target capability under the Administration's plan; choice among the range depends on notions of what is needed to deter a nuclear war and, if deterrence fails, to provide U.S. leaders with appropriate retaliatory options.

Costs to achieve this added capability would be substantial. Between now and the year 2000, the United States would spend $26 billion to complete development and to procure 844 Trident II missiles. About 90 percent of these costs would go toward procurement, since development has largely been completed. In 1987 alone, the Administration would spend $3.1 billion to continue development of the Trident II and to procure 21 missiles (see Summary Table).

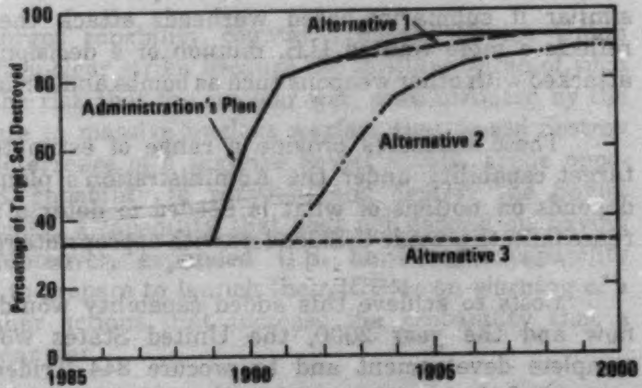
Summary Figure 1.
Administration's Plan and Alternatives: Performance of U.S. ICBMs and SLBMs Against a Large Target Set, Fiscal Years 1985-2000



Summary Figure 2.
Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Large Target Set, Fiscal Years 1985-2000



Summary Figure 3.
Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTE: A large target set (Summary Figure 1 and Summary Figure 2) is 2,000 facilities; a small target set (Summary Figure 3) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 2,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed. Alternative 1 = Cancel Backfits; Alternative 2 = Delay Procurement of Trident II Missiles; Alternative 3 = Cancel Trident II Program.

SUMMARY TABLE PROGRAM COSTS FOR THE ADMINISTRATION'S TRIDENT II PROGRAM AND SAVINGS UNDER ALTERNATIVE PLANS (Fiscal years; budget authority in billions of 1987 dollars)

	1987	1987-1991	Total Program (1987-2030)
Costs for the Administration's Plan			
Investment a/	3.1	13.4	26.1
Other b/	4.3	21.7	78.5
Total	7.4	35.1	104.6
Savings from the Administration's Plan			
Alt 1: Cancel Backfits	c/	0.5	5.3
Alt 2: Reduce and Delay Trident II	0.4	1.4	2.9
Alt 3: Cancel Trident II	0.4	2.0	9.6

SOURCE: Congressional Budget Office.

NOTE: Budget figures do not include the cost of procuring ballistic missile warheads. These costs, which are paid by the Department of Energy, are classified.

a. Includes research and development, procurement, and military construction for the Trident II missile.

b. Includes operating and support costs for the Trident and Poseidon submarines; flight tests for Trident I and Trident II missiles; procurement of Trident submarines; the cost of converting the first eight Trident submarines to carry Trident II missiles (if applicable); and the cost of converting submarines under construction to carry Trident I missiles (if applicable).

c. Savings in fiscal year 1987 would be $2.5 million.

Nor are these the only costs associated with the Administration's Trident II program. More submarines would be bought and operated, and the Trident submarines already carrying the Trident I missile would have to be modified to carry the Trident II missiles. Between now and the year 2030--at which time only a few Trident submarines would still be operating--the total cost of the Trident program would amount to about $105 billion.

ALTERNATIVES TO THE ADMINISTRATION'S PLAN

To hold down costs or to reduce growth in hard-target capability, the Congress could consider alternatives to the Administration's plan. None of the alternatives in this study would greatly alter the total number of U.S. ballistic missile warheads planned by the Administration. But the alternatives would alter the proportion of warheads with hard-target capability and the cost of deploying those warheads. Alternatives include:

- Cancel plans to backfit the first eight Trident submarines with Trident II missiles.
- Reduce and delay procurement of the Trident II by canceling the backfit program and deploying the Trident I on four additional Trident submarines.
- Cancel the entire Trident II program and deploy the Trident I missile on 20 Trident submarines.

Alternative 1: Cancel Backfits

Eliminating the current plan to backfit the eight Trident submarines designed to carry the Trident I missile with Trident II missiles would allow substantial growth in U.S. hard-target capability, though less than would occur under the Administration's plan. This alternative would also achieve long-term savings by making fuller use of the Trident I missiles, some of which would be retired early under the Administration's plan.

Under this alternative, only 12 Trident submarines--the ninth through the twentieth--would be deployed with Trident II missiles. As a result, the number of hard-target warheads on ballistic missiles by the year 2000 would decrease from 6,800 under the Administration's plan to 4,880. This change would have only a small effect, however, on the ability of U.S. SLBMs to conduct retaliatory strikes. The percentage of a hypothetical target set of 2,000 hardened facilities that could be destroyed by U.S. SLBMs, for example, would decrease from 85 percent under the Administration's plan to 75 percent (see Summary Figure 2).

This option would save money by eliminating the conversion of the first eight Trident ships and reducing procurement of the Trident II by 187 missiles. No new Trident I missiles would be needed, even though the test program for the Trident I would be extended. Savings in the near-term would be small ($2.5 million in fiscal year 1987 and $63 million in fiscal year 1988), but $5.3 billion would be saved over the course of the program.

Alternative 2: Reduce and Delay the Trident II Program

By delaying the Trident II program, this alternative would achieve greater near-term savings and would result in the deployment of fewer hard-target warheads than the previous alternative. Long-term savings, however, would be lower.

In addition to canceling the backfit of the first eight Trident submarines, this alternative would reconfigure the ninth through twelfth submarines--which are already under construction and are designed to accommodate the Trident II missile--to carry Trident I missiles. Therefore, only eight Trident submarines would eventually carry the Trident II missile. Because the Trident II missile would not be required until the thirteenth Trident submarine is deployed, near-term savings could be achieved by postponing procurement of the Trident II until 1990.

By the year 2000, this approach would reduce the number of U.S. hard-target warheads on ballistic missiles by 40 percent and would have a significant effect on U.S. ability to retaliate with SLBMs against a large target set. The ability of U.S. SLBMs to destroy the hypothetical target set of 2,000 targets, for example, would decrease from 85 percent under the Administration's plan to about 63 percent (see Summary Figure 2).

This alternative would also affect deployment schedules and test programs. Reconfiguring the ninth through twelfth submarines could cause each submarine to be delayed by up to two years, although this could be compensated for by extended deployment of Trident I missiles on Poseidon submarines. The Trident I flight-test program--designed to update estimates of missile reliability and accuracy--would be extended to support Trident I deployments. The test program, however, would be reduced to six flights per year, which is the minimum necessary to meet guidelines set by the Joint Chiefs of Staff.

The savings in this option reflect cost reductions partially offset by increases. On the one hand, modification of the first eight submarines would be canceled and the procurement of Trident II missiles would be delayed by three years and reduced by 328 missiles. On the other hand, sustaining the Trident II research program during the three-year delay in procurement would add to costs and reduce the efficiency of the Trident II program. Modifications to the ninth through twelfth submarines, extended deployment of the Poseidon submarines, and modification of the Trident base at Kings Bay, Georgia, to handle Trident I missiles would also add to costs. Thus, although this option would save more in 1987 than the previous alternative, it would save less in the long term. Net savings would be $0.4 billion in fiscal year 1987 and $1.4 billion in fiscal years 1987 through 1991. Savings over the total program would be $2.9 billion.

Alternative 3: Cancel the Trident II Missile

This alternative, by canceling the Trident II program at the end of fiscal year 1986, would generate larger savings and less hard-target capability than either of the previous alternatives. The Trident I production line would be reopened to provide enough Trident I missiles to fill 20 Trident submarines and to conduct a flight-test program at the level currently planned for the Trident II missile.

Canceling the Trident II program would eliminate deployment of hard-target warheads on U.S. submarines. Thus, the only growth in the U.S. inventory of hard-target warheads on ballistic missiles would be from the deployment of new ICBMs. This alternative therefore would have a significant impact on U.S. ability to retaliate with SLBMs against both large and small target sets. The percentage of the hypothetical set of 2,000 targets that could be destroyed by U.S. SLBMs in the year 2000, for example, would decrease from 85 percent under the Administration's plan to 32 percent (see Summary Figure 2). Unlike the other alternatives, this one would also have a strong impact on U.S. capability to retaliate against the small set of 500 targets. The percentage of that target set that could be destroyed by U.S. SLBMs would decrease from 93 percent under the Administration's plan to 33 percent (see Summary Figure 3).

As in the previous alternative, savings reflect increases and decreases in costs. Savings stem mostly from canceling procurement of 844 Trident II missiles and from eliminating the modification of the first eight submarines. These savings would be partially offset, however, by the cost of converting the submarines under construction to carry the Trident I missile rather than the Trident II. More important, it would be necessary to reopen the Trident I missile line, which would require requalifying contractors, refurbishing tooling, and redesigning and testing parts for which the original materials or components are no longer available. In addition, the submarine port at Kings Bay would need to be modified. These tasks might cost between $3.5 billion and $5.2 billion. Finally, this option would make it impossible for the United States to provide Trident II missiles to the United Kingdom as currently planned. The United Kingdom would therefore have to modify the design of its planned submarines to accommodate the Trident I missile.

If reopening the Trident I line costs $5.2 billion, this option would produce net savings of $0.4 billion in fiscal year 1987 and $2.0 billion over five years (1987-1991). Over the entire program, the savings would be $9.6 billion. If reopening the Trident I line costs only $3.5 billion, additional savings of $1.7 billion could be achieved between fiscal years 1987 and 1990. These savings would have to be weighed against the loss in hard-target capability and the time-consuming and costly efforts needed to resume production of the Trident I missile.

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If reopening the Trident I line costs $3.9 billion, this option would produce net savings of $0.4 billion in fiscal year 1987 and $2.9 billion over five years (1987-1991). Over the entire program, the savings would be $9.9 billion. If reopening the Trident I line costs only $2.5 billion, additional savings of $1.7 billion could be achieved between fiscal years 1987 and 1990. These savings would have to be weighed against the loss in hard-target capability and the time-consuming and costly efforts needed to resume production of the Trident I missile.

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This alternative, by cancelling the Trident II program in fiscal year 1988, would generate larger savings and less hard-target capability than either of the previous alternatives. The Trident I production line would be reopened to provide enough Trident I missiles to fill 20 Trident submarines and to conduct a flight-test program at the level currently planned for the Trident II missile.

Canceling the Trident II program would eliminate deployment of hard-target warheads on U.S. submarines. Thus, the only growth in the U.S. inventory of hard-target warheads on ballistic missiles would be from the deployment of new ICBMs. This alternative therefore would have a significant impact on U.S. ability to retaliate with SLBMs against both large and small target sets. The percentage of the hypothetical set of 2,000 targets that could be destroyed by U.S. SLBMs in the year 2000, for example, would decrease from 55 percent under the Administration's plan to 32 percent (see Summary Figure 2). Unlike the other alternatives, this one would also have a strong impact on U.S. capability to retaliate against the small set of 860 targets. The percentage of that target set that could be destroyed by U.S. SLBMs would decrease from 53 percent under the Administration's plan to 32 percent (see Summary Figure 3).

As in the previous alternative, savings reflect increases and decreases in costs. Savings stem mainly from canceling procurement of 844 Trident II

CHAPTER I

INTRODUCTION

The United States maintains three types of strategic nuclear weapons: bombers, land-based missiles, and submarine-based missiles. The purpose of this triad is to deter the Soviet Union from initiating a nuclear war and, if deterrence should fail, to enable the United States to employ nuclear forces in a manner deemed appropriate by the national command authority. To ensure that the United States maintains strategic forces that fulfill these objectives, President Reagan announced in 1981 an ambitious plan for upgrading the U.S. strategic triad. Although many details of that plan have been adjusted during the last five years, major programs are under way in all three legs of the triad.

U.S. STRATEGIC FORCES

The United States currently has about 240 B-52 bombers and 56 FB-111 bombers available for strategic missions. To upgrade the bomber force, the United States is deploying air-launched cruise missiles (ALCMs) on B-52 bombers, procuring 100 B-1B bombers, and developing an advanced technology bomber (ATB). 1/ Bombers can either fly into the Soviet Union to deliver nuclear weapons or fire the long-range ALCMs from outside the Soviet Union's borders. One advantage of the bombers is that they can be launched and, in the event of a change in war plans, recalled.

Minuteman intercontinental ballistic missiles (ICBMs) are housed in concrete silos and are the only U.S. forces that currently have the speed, accuracy, and yield to reach the Soviet Union quickly and to destroy targets, such as Soviet ICBM silos, that have been hardened to withstand a nuclear attack. The United States has 450 single-warhead Minuteman II ICBMs and

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1. As B-1Bs are deployed, the primary mission of B-52Gs that have not been modified to carry cruise missiles will be changed to the support of conventional forces. A total of 90 B-52Gs have been modified to carry air-launched cruise missiles (ALCMs) and B-52Hs are currently being modified. Approximately 40 B-52Hs can be modified before the SALT II limit is reached on ballistic missiles with multiple independently targetable reentry vehicles (MIRVs) and bombers with ALCMs. That limit will probably be reached in December of this year.

550 triple-warhead Minuteman III ICBMs deployed in underground silos. To upgrade the ICBM force, the United States will soon deploy 50 10-warhead MX ICBMs that will have much greater capability to destroy hardened Soviet facilities. The Administration is asking the Congress to authorize deployment of another 50 MX ICBMs and is developing plans for a small mobile ICBM.

Finally, the United States has submarines that carry submarine-launched ballistic missiles (SLBMs). Submarines are a particularly important part of the triad of strategic weapons because, when at sea, they are less vulnerable to an attack by the Soviet Union than either bombers or ICBMs based in silos, thus helping to ensure that U.S. strategic weapons would survive a nuclear first strike by the Soviet Union and be able to retaliate. The United States has 28 Poseidon submarines and eight Trident submarines designed to carry SLBMs. Twelve of the 28 Poseidon submarines have been modified to carry 16 eight-warhead Trident I SLBMs. The United States will probably continue to retire the aging Poseidon submarines and build toward a force of 20 Trident submarines, each of which will carry 24 SLBMs.

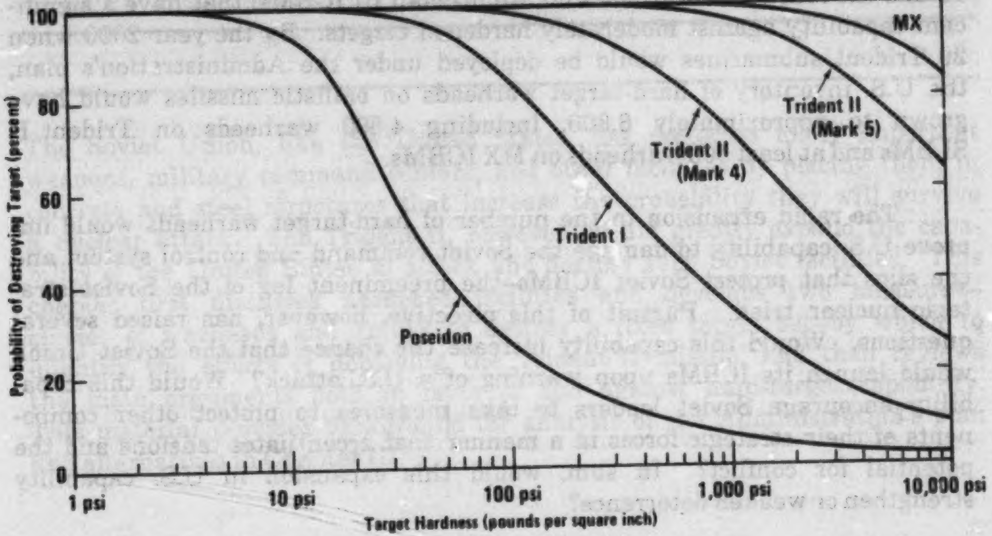
DEPLOYING THE TRIDENT II MISSILE: THE ADMINISTRATION'S PLAN

The Administration plans to deploy the Trident II missile aboard the Trident submarines, thereby exploiting the ability of those submarines to carry larger and more powerful SLBMs. The seven Trident submarines currently deployed and the eighth, which began sea trials in May 1986, are designed to carry the Trident I ballistic missile. According to the Administration's plan, however, the ninth and subsequent Trident submarines would be equipped with the new Trident II ballistic missile. When the first eight Trident submarines receive an overhaul after about 10 years of service, they will be "backfitted" with the Trident II missile--that is, the Trident I missiles will be taken out and replaced with Trident II missiles.

Deploying the Trident II missile would greatly increase the capability of the sea-based leg of the U.S. strategic nuclear triad, replacing existing missiles with more powerful and accurate missiles. Whereas the Trident I carries eight Mark 4 warheads, the Trident II would be able to carry either 11 to 13 Mark 4 warheads or six to nine Mark 5 warheads, which are heavier and have a higher yield. In addition, the Trident II would be about twice as accurate as the Trident I as a result of modifications developed through the Improved Accuracy Program, an intensive study by the Navy designed to find and remedy the sources of inaccuracy in ballistic missile trajectories.

Figure 1.

Capability of Ballistic Missile Warheads Against the Target Spectrum



SOURCE: Congressional Budget Office.

NOTE: Warhead capability is measured here by Single Shot Kill Probability (SSKP)—the probability that an arriving warhead will destroy a target of given hardness. For the method used in calculating the SSKP, see Appendix A.

The greater accuracy and higher yield of the Trident II equipped with Mark 5 warheads would greatly improve the effectiveness of the missile against targets hardened to withstand a nuclear attack. Consider the ability of warheads to destroy a very hard facility such as an ICBM silo that has been strengthened so it has only a 50 percent probability of suffering major structural damage if exposed to 5,000 pounds per square inch (psi) of overpressure. 2/ If a Mark 4 warhead on a Trident I missile reaches the 5,000-psi target and detonates, the probability that it will destroy the target--known as the Single Shot Kill Probability (SSKP)--is about 15 percent. The SSKP of the Mark 4 and Mark 5 warheads on the Trident II missile against a 5,000-psi target is about 40 percent and 80 percent, respectively (see Figure 1 above). The Mark 5 warheads on the Trident II missile are, therefore, nearly as effective against most hardened targets as the warheads on the MX ICBM.

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2. Overpressure is pressure exerted on a surface in excess of standard atmospheric pressure, which is 14.7 pounds per square inch. Overpressure can knock down buildings and--if the overpressure is high enough--shake, deform, or crush underground structures.

The deployment of the Trident II would rapidly increase the number of U.S. ballistic missile warheads that can destroy hardened targets. The United States currently has only 1,650 ballistic missile warheads (the Mark 12 and the Mark 12A warheads on Minuteman III ICBMs) that have a significant capability against moderately hardened targets. By the year 2000 when 20 Trident submarines would be deployed under the Administration's plan, the U.S. inventory of hard-target warheads on ballistic missiles would have grown to approximately 6,800, including 4,800 warheads on Trident II SLBMs and at least 500 warheads on MX ICBMs.

The rapid expansion in the number of hard-target warheads would improve U.S. capability to damage the Soviet command and control system and the silos that protect Soviet ICBMs--the preeminent leg of the Soviet strategic nuclear triad. Pursuit of this objective, however, has raised several questions. Would this capability increase the chance that the Soviet Union would launch its ICBMs upon warning of a U.S. attack? Would this capability encourage Soviet leaders to take measures to protect other components of their strategic forces in a manner that accentuates tensions and the potential for conflict? In sum, would this expansion in U.S. capability strengthen or weaken deterrence?

In addition to the hard-target capability of the Trident II missile, questions have been raised about the cost of the system. Between 1987 and the year 2000, the Administration's plans call for spending $26.1 billion in budget authority (in fiscal year 1987 dollars) to develop and procure Trident II missiles. Is the high cost of procuring the Trident II missile justified by its greater payload and accuracy? Might it be more efficient to rely on the successful Trident I missile until it approaches the end of its service life, rather than replacing it earlier with the Trident II?

This study analyzes these two issues--hard-target capability and cost--to provide a foundation for understanding the differences between the Trident I and Trident II missile programs. Chapter II assesses hard-target capability and reviews the arguments for and against expanding this capability. Chapter III presents the effect on cost, scheduling, and hard-target capability of the Administration's plan and of three alternatives that would deploy more Trident I missiles in place of Trident II missiles.

CHAPTER II

ASSESSING HARD-TARGET CAPABILITY

The Soviet Union, like the United States, has protected many important weapons, military command centers, and other facilities by placing them in concrete and steel structures that increase the probability they will survive a nuclear attack. The Trident II, however, would greatly expand the capability of the United States to attack and destroy such Soviet facilities. This chapter first discusses hardened facilities and develops two measures--classes of warheads and ability to destroy a fixed target set--by which to quantify the effects of deploying the Trident II missile, and then reviews the main arguments both in favor of and against hard-target capability. This material provides background for analysis of the Administration's plan and alternatives in Chapter III.

DEFINING HARDENED FACILITIES

The detonation of a nuclear weapon produces many effects including heat, electromagnetic pulse, wind, radiation, shock waves, and a crater. Although a facility can be protected from most of these effects by being located underground in a concrete, steel-reinforced structure, it is not currently possible to provide significant protection for any facility that is within the crater dug by a blast. In addition, a structure located outside the crater of a blast is exposed to the crushing force of shock waves and their secondary effects, which include the movement of components within a structure and vibration. Such secondary effects can, for example, disable an ICBM--even if the ICBM silo is structurally undamaged--by causing the ICBM to collide with the wall of the silo or by causing electrical components to fail as a result of vibration.

These destructive effects are difficult to evaluate, and significant uncertainty exists regarding the size of nuclear blast required for a particular probability of disabling a facility. Given this uncertainty, it is common to assume the worst case: a Soviet facility will survive and perform its function unless the facility suffers major structural damage. Thus, the hardness of a facility can be evaluated according to the size of blast--measured by the highest or "peak" overpressure of the blast--at which the facility has a 50 percent chance of suffering major structural damage. For example, a

TABLE 1. SYSTEM FOR RATING THE HARDNESS OF TARGETS

Hardness Rating	Hardness (pounds per square inch)	Types of Targets
Soft	0-50	Vehicles Buildings
Medium-hard	50-1,000	Munitions bunkers Leadership bunkers Command and control centers Older Soviet ICBM silos
Hard	1,000-3,000	Minuteman ICBM silos
Very Hard	Over 3,000	Newer Soviet ICBM silos Tunnels for submarines

SOURCE: Congressional Budget Office.

facility hardened to 5,000 pounds per square inch (psi) has a 50 percent probability of suffering major structural damage from a 5,000-psi peak overpressure. 1/ This system of rating the hardness of facilities was employed in this study and is summarized in Table 1. Because of the factors mentioned above, however, extensive damage might occur to facilities exposed to levels of overpressure far lower than the level at which they are rated.

The facilities that the United States and the Soviet Union have hardened fall roughly into three groups. Soviet silos for single-warhead

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1. The probability that a facility will survive a blast depends on the duration of the period of high overpressures as well as on the peak overpressure. For example, a particular silo might have a 50 percent probability of surviving a peak overpressure of 5,000 psi generated by a warhead with a large explosive power or "yield" and an associated long period of high overpressures. The same silo might also have a 50 percent probability of surviving a peak overpressure of 6,000 psi generated by a warhead with a smaller yield and an associated shorter period of high overpressures. For simplicity, therefore, the duration of the period of high overpressures is normally turned into a function of peak overpressure by establishing a reference yield. In this paper, the reference yield is one megaton (1,000 kilotons), meaning that the yield of the reference explosion is equivalent to the explosive power generated by one megaton of TNT.

ICBMs and shallow underground structures such as munitions bunkers, leadership bunkers, and command and control centers might range in hardness, based on the system described above, from 50 psi to 1,000 psi. These structures are referred to in this study as "medium-hard" targets. 2/ "Hard" structures, such as Minuteman ICBM silos, might range in hardness from 1,000 to 3,000 psi. Finally, command and control centers deep underground, tunnels for submarines, and Soviet silos for multiple-warhead ICBMs probably have a hardness greater than 3,000 psi and are referred to as "very hard" targets. 3/ Facilities hardened to less than 50 psi are "soft" targets.

MEASURING HARD-TARGET CAPABILITY

Just as the hardness of targets varies, so does the capability of warheads against those targets. The probability that a warhead will destroy a target depends both on system reliability (the probability that the missile will deliver the warhead to the target and that the warhead will detonate) and the warhead's Single Shot Kill Probability (SSKP--the probability that a warhead will destroy a target of specified hardness when it arrives and detonates). 4/ The SSKP of a warhead is a function of both the explosive power or "yield" of the warhead and its accuracy. 5/ The yield of a warhead is measured by the kilotons of TNT that would be required for an explosion of similar power. The accuracy of a warhead is measured by the Circular Error Probable (CEP), the radius of a circle drawn around a target

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2. Of the approximately 1,400 Soviet ICBMs, about 500 are older single-warhead ICBMs (the SS-11 and the SS-13) that are probably based in medium-hard silos. The SS-11 silos, for example, reportedly were hardened only to between 200 and 400 psi (see Robert Berman and John Baker, *Soviet Strategic Forces* (Washington, D.C.: Brookings Institution, 1982), p. 91). Some uncertainty exists as to whether the SS-11 silos were hardened further, but statements by the Department of Defense (DoD) suggest they have not been (see DoD, *Soviet Military Power* (1986), p. 24).

3. Silos for Soviet ICBMs with multiple independently targetable reentry vehicles (MIRVs)--the SS-17, SS-18, and SS-19--are commonly reported to be hardened to between 4,000 and 6,000 psi. See *Jane's Weapon Systems* (London: Jane's Publishing Company, 1985), p. 8; *Aviation Week and Space Technology* (October 12, 1981), p. 22.

4. In this study, all calculations of the capability of a group of ballistic missile warheads to destroy a set of targets assume a missile system reliability of 80 percent. Although some missiles are more reliable than others, this assumption is made for three reasons. First, all point estimates of missile reliability have an accompanying band of uncertainty. Second, missile tests cannot completely emulate the conditions that would prevail during wartime. Third, there is very little public information on the reliability of either U.S. or Soviet ballistic missiles.

5. The accuracy of ballistic missile warheads is affected by many factors including the ability of the missile to place the warhead on the correct trajectory and by characteristics (continued)

such that a warhead aimed at the target has a 50 percent chance of detonating within or above the circle.

The yield of a warhead affects its SSKP because a higher yield creates a higher peak overpressure at any given radius from the blast. Since the level of overpressure dissipates rapidly as the distance from the blast increases, however, high accuracy greatly increases the probability that the target will be destroyed. For example, a Mark 4 warhead on a Trident I missile has about a 15 percent SSKP against a 5,000-psi silo. 6/ That same warhead on the more accurate Trident II has about a 40 percent SSKP against a 5,000-psi silo. A Mark 5 warhead, which has four to five times the yield of the Mark 4, has about an 80 percent SSKP if carried on the accurate Trident II.

Classification of Hard-Target Warheads

Hardened targets can, as noted above, be divided into three groups that differ markedly in their ability to resist the destructive effects of shock waves. Thus, since the ability of a warhead to destroy a target varies greatly according to the target's degree of hardness, classifying warheads simply as soft- or hard-target warheads can be misleading. To account for this relationship between warhead capability and target hardness, the Congressional Budget Office (CBO) established three classes of hard-target warheads in this study, defined by the SSKP of a warhead against targets representative of the three ranges of hardness.

Under this system of classification, warheads that have a combination of accuracy and yield resulting in an SSKP of greater than 70 percent against a 5,000-psi (very hard) target are labeled Class 1 hard-target warheads. 7/ Of the U.S. ballistic missile warheads, only the forthcoming Mark

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5. (continued)
of the warhead that influence its trajectory after it reenters the atmosphere. The ability of the missile to place the warhead on the correct trajectory depends in part on the distance between the missile launch and the target. In general, accuracy is better when the distance is shorter; the U.S. Navy uses a reference range when citing the CEP of a missile. For a mobile missile such as an SLBM, the ability of the missile to place the warhead on the correct trajectory also depends on the stability of the launch platform (for SLBMs, the launch platform is the submarine) and the precision with which the location of the launch platform can be established. Accuracy can also be affected by weather, the location of stars used in a stellar update guidance system, and other factors.

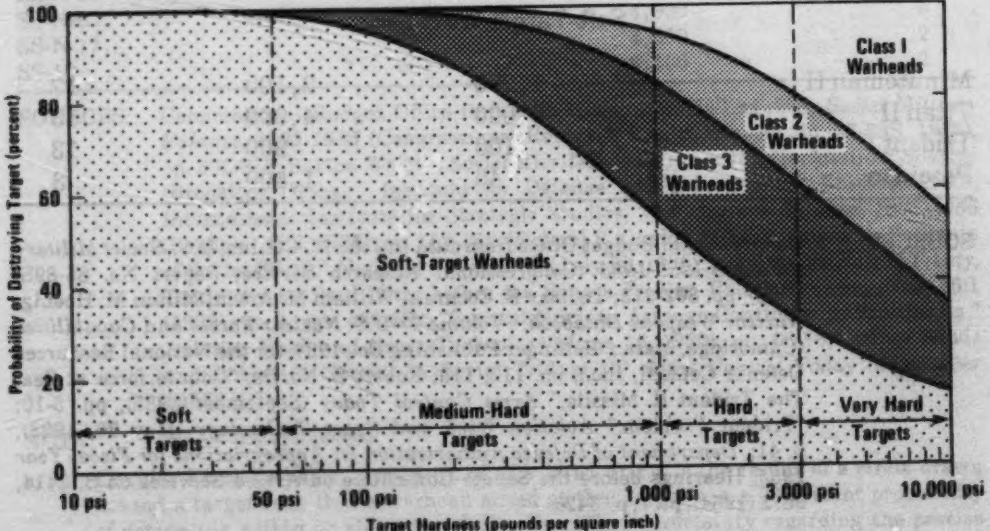
6. See Appendix A for the method used in making SSKP calculations.

7. An SSKP of 70 percent was chosen as the standard because two warheads with an SSKP of 70 percent would provide a high probability (greater than 90 percent) of destroying a target.

21 warhead on the MX ICBM and the Mark 5 warhead on the Trident II SLBM would meet that standard (see Table 2). None of the Soviet ballistic missile warheads currently meet that standard. Warheads that do not meet that standard but that have a 70 percent SSKP against a 2,000-psi target are Class 2 hard-target warheads. The Mark 12A warheads on the U.S. Minuteman III and warheads on the Soviet SS-18 (Mod 4) and SS-25 fall into that class (see Table 3). Class 3 hard-target warheads meet neither of the above standards but have an SSKP of 70 percent against a 500-psi target. The U.S. ballistic missile warheads in this class are the Mark 4 warheads on the Trident II missile and the Mark 12 warheads on the Minuteman III missile. Warheads on the Soviet SS-17 (Mod 3), SS-19 (Mod 3), and probably the forthcoming SS-24 also belong in that class. The capability of warheads in these classes against the full range of hardened targets is shown in Figure 2.

Figure 2.

Capability of Ballistic Missile Warheads, by Class, Against the Target Spectrum



SOURCE: Congressional Budget Office.

NOTE: Warhead capability is measured here by Single Shot Kill Probability (SSKP) — the probability that an arriving warhead will destroy a target of given hardness. Class 1 warheads have an SSKP of at least 70 percent against a 5,000-psi target. Class 2 warheads do not meet that standard but have an SSKP of at least 70 percent against a 2,000-psi target. Class 3 warheads do not meet either of those standards but have an SSKP of at least 70 percent against a 500-psi target. All other warheads are soft-target warheads.

TABLE 2. CLASSIFICATION OF CURRENT U.S. BALLISTIC MISSILE WARHEADS

Warheads	Yield (kilotons)	CEP a/ (feet)	SSKP b/ (percent)
Class 1 Hard-Target Warheads			
MX Mark 21 c/	300	300	93
Trident II Mark 5 c/	475	500	79
Class 2 Hard-Target Warheads			
Minuteman III Mark 12A	335	600	57
Class 3 Hard-Target Warheads			
Minuteman III Mark 12	170	600	39
Trident II Mark 4	100	500	37
Soft-Target Warheads			
Minuteman II	1,200	2,100	17
Titan II	9,000	4,900	13
Trident I	100	900	13
Poseidon	40	1,500	3

SOURCES: Congressional Budget Office from data in John M. Collins, *U.S.-Soviet Military Balance, 1980-1985* (Congressional Research Service, Report No. 85-89S, 1985), pp. 302-313; Thomas B. Cochran, William M. Arkin, Milton M. Hoenig, *Nuclear Weapons Databook: Volume 1--U.S. Nuclear Forces and Capabilities* (Cambridge, Mass.: Ballinger Publishing Co., 1984, for the National Resources Defense Council, Inc.), pp. 113, 118; Robert S. Norris, "Counterforce at Sea: The Trident II Missile," *Arms Control Today* (September 1985), pp. 5-10; "Trident Problem," *Aviation Week and Space Technology* (May 30, 1983), p. 41; *Department of Defense Authorization for Appropriations for Fiscal Year 1985*, Hearings before the Senate Committee on Armed Services on S. 2414, 98:2 (1984), pt. 7, p. 3426.

a. Circular Error Probable is a measure of missile accuracy. It is equal to the radius of a circle drawn around a target such that a warhead aimed at that target has a 50 percent probability of detonating within or above the circle. To reflect uncertainty regarding the precise CEP of each system, all CEP estimates have been rounded to the nearest 100 feet.

b. Single Shot Kill Probability against a silo hardened to 5,000 psi. See Appendix A for a description of the method used in the calculation.

c. Forthcoming.

TABLE 3. CLASSIFICATION OF CURRENT SOVIET BALLISTIC MISSILE WARHEADS

Warheads	Yield (kilotons)	CEP a/ (feet)	SSKP b/ (percent)
Class 1 Hard-Target Warheads			
None c/	n.a.	n.a.	n.a.
Class 2 Hard-Target Warheads			
SS-25 d/	550	600	69
SS-18 (Mod 4)	500	700	54
Class 3 Hard-Target Warheads			
SS-24 d/	100	600	27
SS-17 (Mod 3)	500	1,200	24
SS-19 (Mod 3)	550	1,300	22
Soft-Target Warheads			
SS-N-23 d/	250	2,000	6
SS-11	1,000	3,600	6
SS-N-18	500	3,000	5
SS-N-6	1,000	4,200	4
SS-N-20	100	1,800	4
SS-N-8	800	4,900	3
SS-N-17	500	4,600	2
SS-13	600	6,100	2

SOURCES: Congressional Budget Office from data in John M. Collins, *U.S.-Soviet Military Balance, 1980-1985* (Congressional Research Service, Report No. 85-89S, 1985), pp. 302-313; Barton Wright, *Soviet Missiles: Data From 100 Unclassified Sources* (Brookline, Mass.: Institute for Defense and Disarmament Studies, 1985); International Institute for Strategic Studies, *The Military Balance, 1985-1986* (London: IISS, 1985), pp. 158-165; Michael R. Gordon, "CIA Downgrades Estimate of Soviet SS-19," *National Journal*, 29 (July 20, 1985), p. 1692; *The Salt II Treaty*, Testimony by Paul Nitze before the Senate Foreign Relations Committee, 96:1 (1979), pt. 1, pp. 439-482; "Soviets' Nuclear Arsenal Continues to Proliferate," *Aviation Week and Space Technology* (June 16, 1980), pp. 68-76; Jeffrey Sands and Robert S. Norris, "A Soviet Trident II," *Arms Control Today* (September 1985), p. 7.

NOTE: n.a. = not applicable.

a. Circular Error Probable, a measure of missile accuracy, is the radius of a circle drawn around a target such that a warhead aimed at that target has a 50 percent probability of detonating within or above the circle. To reflect uncertainty regarding the precise CEP of each system, CEP estimates have been rounded to the nearest 100 feet.

b. Single Shot Kill Probability against a silo hardened to 5,000 psi. See Appendix A for a description of the method used in the calculation.

c. According to the DoD, the Soviet Union has retired all SS-18 (Mod 1), SS-18 (Mod 3), and SS-19 (Mod 2) ICBMs. The warheads on these missiles were Class 1 warheads.

d. Estimates of the yield and CEP for the newly deployed SS-25 and the forthcoming SS-24 and SS-N-23 are speculative. If the SS-25 warhead has slightly better yield or accuracy than noted above, it would belong in Class 1. If the SS-24 warhead has a much larger yield than noted above (for example, 300 kt), it would belong in Class 2.

Other ballistic missile warheads, including those on the SS-11 ICBM, SS-13 ICBM, and all Soviet SLBMs, are soft-target warheads. U.S. warheads in this category include those on the Minuteman II ICBM, Trident I SLBM, and Poseidon SLBM.

Number of Hard-Target Warheads

The three classes of warheads can be used to evaluate the growth in the number of U.S. and Soviet strategic hard-target warheads. In this study, however, only the growth in strategic ballistic missile capability--ICBMs and SLBMs--will be measured. Weapons on strategic bombers, sea-launched cruise missiles (SLCMs), and nuclear weapons based in Western Europe (ground-launched cruise missiles (GLCMs) and Pershing II ballistic missiles) are not measured because they are designed for different missions. 8/

Whereas warheads on ICBMs and SLBMs can reach their targets in 15 to 30 minutes and therefore are referred to as "prompt" warheads, bomber-delivered ordnance--bombs, air-launched cruise missiles (ALCMs), and short-range attack missiles (SRAMs)--require several hours. 9/ Therefore, although bombs and ALCMs--and probably the next generation of SRAMs--can be highly effective against hardened targets, the time required for their delivery makes them ineffective in "time-urgent" missions such as destroying Soviet ICBMs while they are still in their silos, and destroying Soviet command and control centers before crucial decisions can be made and communicated. SLCMs, like ALCMs, fly slowly and thus are ineffective against time-urgent targets. 10/ GLCMs and Pershing II missiles, which are stationed in Western Europe, are designed to deter and respond to an attack on Western Europe rather than on the United States.

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8. Cruise missiles (SLCMs, GLCMs, and air-launched cruise missiles) are unmanned, jet-propelled, flying vehicles programmed to carry explosives to a target. They fly slowly (at less than the speed of sound) and are guided to their targets both by an inertial navigation system and by terrain contour matching.

9. U.S. ALCMs are designed to carry only nuclear warheads and to be launched from strategic bombers. They can be carried either in the weapons bay or on pylons attached to the wings. The range of ALCMs is approximately 2,500 kilometers (km). SRAMs are rocket-propelled, inertially guided, air-to-surface missiles. Their speed (three to four times the speed of sound) and range (50-200 km, depending on the altitude at which they fly) enable bombers to attack air defenses or other facilities before they fly near them.

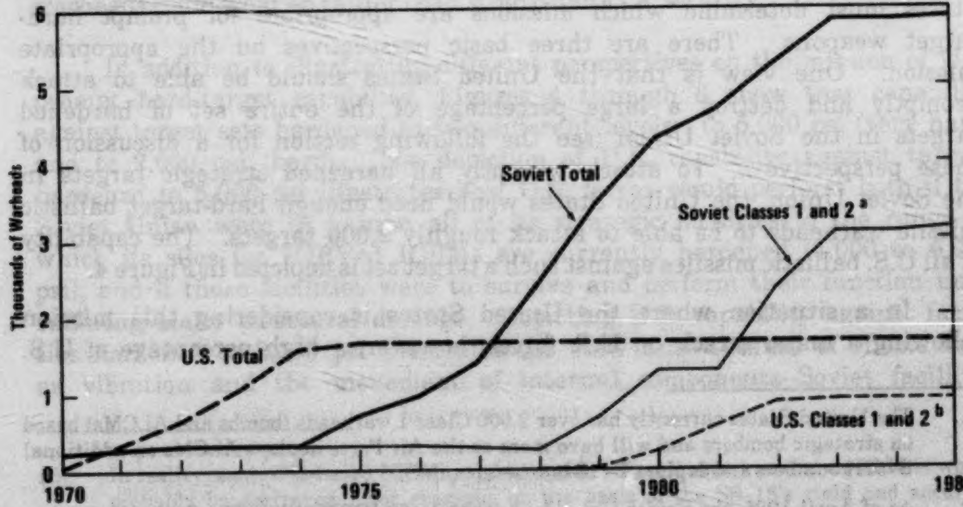
10. The nuclear land attack version of the SLCM, which has been deployed for less than three years, has the range (2,500 km), yield (200-250 kt), and accuracy to destroy hardened targets in the Soviet Union. Using SLCMs as part of a coordinated strategic attack on the Soviet Union, however, would be complicated because they are carried on ships and submarines that have conventional naval responsibilities.

Figure 3 shows the growth of U.S. and Soviet prompt strategic hard-target warheads. The United States started to deploy ICBMs with multiple independently targetable reentry vehicles (MIRVs) in the early 1970s and developed a five-to-one lead in prompt hard-target warheads by 1974. The Soviet Union, however, began to close the gap the following year by beginning to deploy the SS-17, SS-18, and SS-19. The Soviet Union had a large lead in prompt hard-target capability by 1980 and expanded that lead through 1983.

Since 1983, the number of prompt hard-target weapons possessed by both nations has been stable, with the Soviet Union maintaining its lead. The Soviet Union now has about 2,800 Class 3 prompt hard-target warheads compared with 750 for the United States. Similarly, the Soviet Union has approximately 3,200 Class 2 prompt hard-target warheads; the United States

Figure 3.

Number of U.S. and Soviet Ballistic Missile Hard-Target Warheads, Fiscal Years 1970-1985



SOURCE: Congressional Budget Office.

NOTE: The U.S. and Soviet totals count all three classes of hard-target warheads deployed on ballistic missiles. Class 1 warheads have a Single Shot Kill Probability (SSKP) of at least 70 percent against a 5,000-psi target. Class 2 warheads do not meet that standard but have an SSKP of at least 70 percent against a 2,000-psi target. Class 3 warheads do not meet either of those standards but have an SSKP of at least 70 percent against a 500-psi target.

[a] The Soviet Union deployed a few Class 1 warheads—the SS-18 (Mod 2) and SS-19 (Mod 2)—between 1975 and 1980. Otherwise, all warheads in this subtotal are Class 2 warheads.

[b] The United States has not deployed any Class 1 warheads to date.

has 900. As noted above, neither nation currently has any Class 1 prompt hard-target warheads. 11/

Capability Against a Target Set

The number of prompt hard-target warheads possessed by the United States, however, only partially reflects the potential effectiveness of those warheads. Other crucial factors are the number of hardened facilities in the Soviet Union, the strategic objective (for example, to attack all strategic targets or only a limited set of targets), and the ability of U.S. warheads to survive an initial strike by the Soviet Union.

The Soviet Union has roughly 2,000 hardened strategic facilities including 1,300 to 1,400 ICBM silos and 600 to 700 other facilities such as command and control centers, warhead bunkers, and submarine tunnels. 12/ The United States must consider which of these facilities must be targeted and which, among those targeted, must be attacked promptly. As noted above, potential time-urgent targets include Soviet ICBM silos and command and control centers.

In addition to determining which targets are time-urgent, the United States must determine which missions are appropriate for prompt hard-target weapons. There are three basic perspectives on the appropriate mission. One view is that the United States should be able to attack promptly and destroy a large percentage of the entire set of hardened targets in the Soviet Union (see the following section for a discussion of these perspectives). To attack promptly all hardened strategic targets in the Soviet Union, the United States would need enough hard-target ballistic missile warheads to be able to attack roughly 2,000 targets. The capability of all U.S. ballistic missiles against such a target set is depicted in Figure 4.

In a situation where the United States is considering this mission following a major attack on U.S. forces, however, a high percentage of U.S.

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11. The United States currently has over 2,000 Class 1 warheads (bombs and ALCMs) based on strategic bombers and will have more as the Air Force deploys ALCMs on additional B-52H bombers and deploys B-1B bombers.

12. As of April 1985, the Soviet Union had about 1,400 ICBM silos. The Soviet Union has replaced more than 70 silo-based SS-11 ICBMs with mobile SS-25 ICBMs during the past year, however, and has begun to dismantle the silos for the SS-11s. The Department of Defense expects the Soviet Union to continue to retire SS-11 ICBMs, probably deactivating all of them by the mid-1990s. Consequently, by the mid-1990s the number of Soviet ICBM silos could decrease to less than 900. (See Department of Defense, *Soviet Military Power* (1986), p. 26.) In addition to hardened strategic targets, the Soviet Union reportedly has 700 hardened leadership bunkers (Jeffrey Richelson, "PD-59, NSDD-13, and the Reagan Strategic Modernization Program," *Journal of Strategic Studies*, vol. 6 (June 1983)).

silo-based ICBMs would probably have been destroyed. The United States then would have to depend primarily on the retaliatory capability of SLBMs (and, if procured, mobile ICBMs) to perform missions against time-urgent targets. 13/ This capability is depicted in Figure 5.

A second perspective is that the United States needs only the ability to conduct a limited retaliatory strike against hardened time-urgent targets in order to strengthen deterrence of a Soviet strike against targets in the United States. In this context, "limited" refers to an attack against a few targets or a subset of targets such as ICBM silos. The number of Soviet facilities targeted in a limited retaliatory attack by the United States might range from just a few to more than 1,000. Figure 6 provides an example of the performance of U.S. SLBMs in this less demanding mission by depicting their capability against a target set of 500 hardened facilities.

The third perspective is that there is no need for the United States to be able to conduct prompt attacks on hardened targets in the Soviet Union and that a strong capability to destroy hardened Soviet targets might increase the likelihood that a crisis would escalate into nuclear war. In this perspective, continued growth in the number of U.S. prompt hard-target warheads could weaken rather than strengthen U.S. security.

In addition to illustrating different perspectives on the mission of U.S. prompt hard-target capability, Figures 4 through 6 show that capability against target sets hardened to two different levels: to 5,000 psi (very hard) and to 2,000 psi (hard). The depiction of U.S. capability against targets hardened to 5,000 psi illustrates how U.S. forces would perform both if the Soviet Union were to harden all of its strategic facilities to the range at which its silos for MIRVed ICBMs are currently hardened (4,000 to 6,000 psi), and if these facilities were to survive and perform their function until suffering major structural damage. Depicting U.S. capability against facilities hardened to 2,000 psi illustrates the view that--because of effects such as vibration and the movement of internal components--Soviet facilities

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13. In reality, some silo-based ICBMs might survive a Soviet attack and some SLBMs would probably be destroyed. For example, on the basis of the SS-18's yield and accuracy presented in Table 3 and an assumed reliability for the SS-18 of 80 percent, about 16 percent of the U.S. Minuteman ICBM missiles would survive an attack by 2,000 SS-18 (Mod 4) warheads without major structural damage (it is assumed that the U.S. silos are hardened to 2,000 psi). The Department of Defense is more optimistic, estimating that 20 percent to 35 percent of the silos would survive (see DoD, *Soviet Military Power* (1986), p. 25). In addition, missile-carrying submarines in drydock or at dockside during an attack would probably be destroyed. During a crisis, however, the United States would seek to maximize the survival of submarines by sending all seaworthy vessels on patrol.

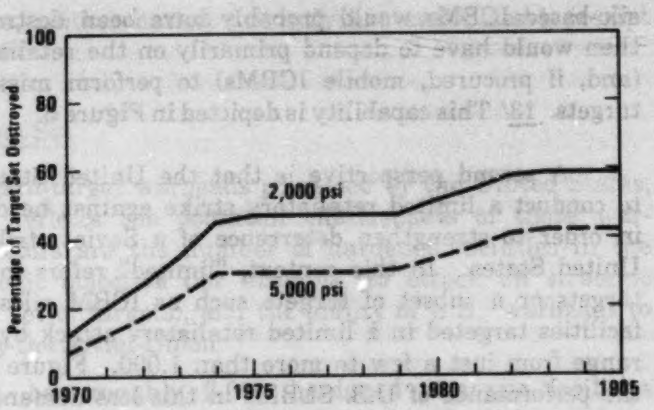

Figure 4.
Performance of U.S. ICBMs and SLBMs Against a Large Target Set, Fiscal Years 1970-1985

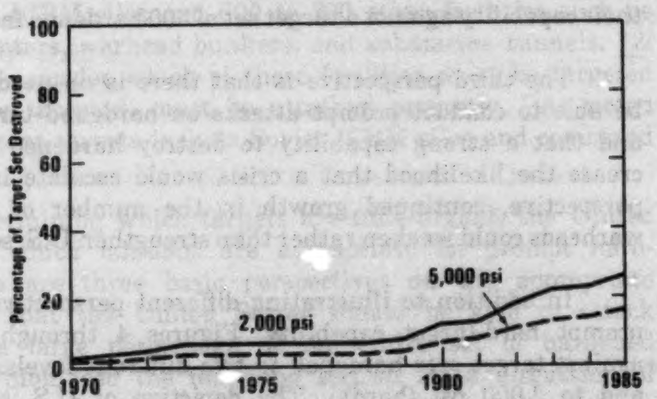

Figure 5.
Performance of U.S. SLBMs Against a Large Target Set, Fiscal Years 1970-1985

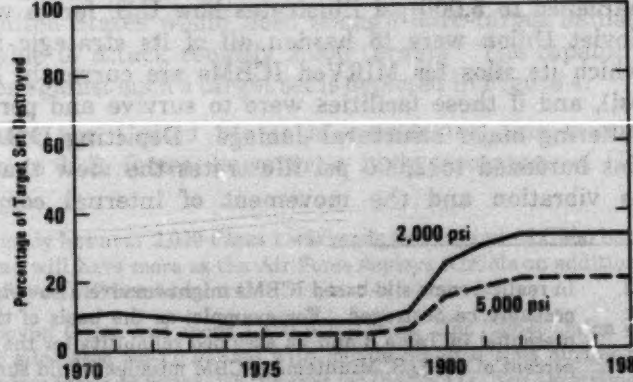

Figure 6.
Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1970-1985

SOURCE: Congressional Budget Office.

NOTES: A large target set (Figures 4 and 5) is 2,000 facilities; a small target set (Figure 6) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 2,000 psi and 5,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed.

might fail long before suffering major structural damage. This view is probably more representative of the way the Soviets would view the survival of their own forces.

PERSPECTIVES ON HARD-TARGET CAPABILITY

The measures developed above--number of hard-target warheads and the capability of warheads against a hardened target set--show substantial growth in hard-target capability under the Administration's plans to deploy the Trident II. Perspectives on the necessity of that growth, however, differ greatly. Proponents and opponents put forward divergent views on such fundamental issues as deterrence, fighting a nuclear war, and crisis stability. This study lays out the main arguments on both sides of the issue but makes no attempt to determine whether additional hard-target capability is needed.

Arguments in Favor of Increasing U.S. Prompt Hard-Target Capability

The Soviet Union has a considerable lead in the deployment of prompt hard-target warheads. At the end of 1985, the Soviet Union had about three and one-half times as many as the United States. This imbalance has drawn attention to the issue of hard-target capability and, more specifically, to the vulnerability of U.S. facilities to a Soviet attack. Increasing U.S. hard-target capability would not decrease the vulnerability of those facilities directly, but, according to proponents, it would decrease their vulnerability indirectly by enhancing U.S. deterrence of an initial Soviet strike.

The argument that an increase in U.S. prompt hard-target capability would enhance deterrence has two parts: deterrence of a "massive" Soviet strike and deterrence of a "limited" Soviet strike. Presidential Directive 59 (PD-59), signed by President Carter and reportedly endorsed by the Reagan Administration in National Security Decision Directive 13 (NSDD-13), 14/ postulates that the deterrence of a massive Soviet strike--that is, a Soviet attack against all of the major military and economic facilities in the

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14. Each U.S. Administration has a system of documents for implementing national security policy decisions made by the President. Under different Administrations, however, these documents are given different titles. President Nixon used National Security Decision Memorandums (NSDMs), President Carter used Presidential Directives (PDs), and President Reagan uses National Security Decision Directives (NSDDs). Although the content of NSDD-13 has been widely reported, the Reagan Administration has not confirmed either the content of the document or its existence.

United States--is maximized if the United States can threaten a retaliatory strike against the targets that Soviet leaders value most. 15/ Thus, on the assumption that the Soviet leaders value most highly the domestic political control structure and military power of the state, the United States has deemphasized the targeting of economic targets (industrial sites and transportation systems) and has emphasized the targeting of Soviet leadership, command and control centers, strategic weapon facilities, and major military facilities supporting conventional forces. Providing full coverage of these Soviet assets might require the deployment of several thousand survivable hard-target warheads.

An increase in the number of U.S. prompt hard-target warheads might also enhance deterrence of a limited Soviet first strike, which might range from an attack on a few targets in the United States to an attack on an entire subset of targets such as U.S. ICBM silos. In arguing for expanded hard-target capability, proponents cite two reasons why the current U.S. capability to respond to a limited Soviet strike with either a limited or a massive attack on soft targets in the Soviet Union might not deter Soviet leaders from conducting such a strike. First, the Soviet Union might not expect the United States to retaliate (for example, the United States might choose not to retaliate against soft urban-industrial targets in the Soviet Union in fear of a counterattack against similar targets in the United States). Second, the Soviet Union might be willing to accept the potential loss of some urban-industrial centers or other soft facilities.

This rationale was reflected in National Security Decision Memorandum 242 (NSDM-242), signed by President Nixon in January 1974, which called for the development of plans for limited retaliatory strikes on diverse sets of Soviet targets. In calling for such plans, NSDM-242 had two objectives. One was to enhance deterrence by increasing the risks faced by Soviet leaders in conducting a limited attack against U.S. facilities. For example, U.S. possession of prompt hard-target warheads (as opposed to hard-target warheads with long delivery times such as ALCMs and bombs), would increase the possibility that the United States might retaliate by striking Soviet ICBM silos with the goal of destroying ICBMs before they could be launched. The second objective was that, should deterrence fail, limited options would increase the flexibility accorded U.S. leaders in determining which type of attack would serve the goal of controlling escalation while resolving the conflict on acceptable terms.

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15. A massive strike would probably include an attack on all major command and control bunkers, military bases, leadership centers, strategic weapons, harbors, and industrial centers. Because of the collocation of many of these facilities with urban areas, all major cities would probably be destroyed regardless of whether they were targeted directly.

Proponents of greater hard-target capability also argue that an increase in the U.S. inventory of hard-target warheads might encourage the Soviet Union to deploy mobile command and control facilities and mobile ballistic missiles (either submarine-based, ship-based, or mobile land-based ballistic missiles). Mobile Soviet facilities would be difficult for the United States to target, potentially enhancing stability by increasing the survivability of the systems and thereby decreasing Soviet incentives to launch them upon warning of an attack. 16/

Finally, proponents of growth in the inventory of hard-target warheads have argued that such growth is an inevitable consequence of improving technology. A U.S. decision not to deploy such warheads would require forgoing the deployment of new missiles, limiting the accuracy of future missiles by retaining obsolescent technology, or reducing significantly the yield of warheads on future missiles. Meanwhile, since the accuracy of Soviet missiles continues to improve, the Soviet lead in hard-target capability would be compounded.

These arguments support the deployment of prompt hard-target warheads, but they do not provide a clear indication of how many are required. Some proponents believe that only a modest number (perhaps several hundred to a thousand) of such warheads are necessary, if deployed in a manner such that they would survive a Soviet attack. A modest number of such warheads, they argue, would accomplish the primary objective of enhancing deterrence, and, in the event deterrence fails, would provide U.S. leaders with the option of conducting prompt limited strikes against hardened targets. Larger attacks on hardened targets could be accom-

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16. Some analysts have noted that by encouraging the Soviet Union to deploy smaller mobile missiles in place of the large silo-based ICBMs, particularly the SS-18, the United States might also reap a side benefit by reducing the current Soviet advantage in ballistic missile throwweight. (Throwweight is the weight of the payload that a missile can deliver to a specified range. It is a measure of strategic capability because it determines the weight and number of warheads that each nation can deploy on ballistic missiles; it does not, however, reflect other important qualities such as range, reliability, the yield-per-weight ratio of the warheads, or their accuracy.)

It does not appear, however, that the potential reduction in Soviet throwweight will be realized. First, unless the missile ceilings imposed by SALT II endure--and they are in doubt following the recent U.S. decision to base future deployments on force requirements rather than on SALT ceilings--the Soviet Union would probably not continue to retire older missiles as it deploys new missiles. Even with SALT ceilings, the Soviet Union might choose to exchange the SS-11 and SS-13 for the road-mobile SS-25 and to exchange the SS-17 and SS-19 for the anticipated rail-mobile SS-24, leaving the major cause of the Soviet throwweight advantage--308 SS-18 missiles--untouched.

plished with weapons that take longer to arrive such as bomber-delivered bombs and ALCMs. Other proponents argue that it is important to provide U.S. leaders with a fuller set of options, possibly including the ability to attack promptly the entire set of hardened targets in the Soviet Union. To accomplish that more demanding mission, far more warheads would be required. For example, to attack the approximately 2,000 hardened strategic targets in the Soviet Union, 4,000 to 5,000 prompt hard-target warheads might be required.

Arguments Against Expanded Hard-Target Capability

Opponents of growth in hard-target capability argue that deterrence is currently strong and that the deployment of additional hard-target weapons would increase rather than decrease the probability that a crisis would escalate to nuclear war.

In regard to the deterrence of a massive Soviet strike, opponents argue that Soviet leaders value their society (citizens and their culture) and the country's economic infrastructure (industrial centers, transportation and communication networks, and agrarian resources) at least as much as they value the means (command and control centers and ballistic missile silos) to protect their society. Therefore, the fundamental deterrent to a massive Soviet strike is the U.S. capability to destroy Soviet cities, industrial centers, highways, pipelines, railroads, ports, airports, and their agrarian system--resulting in the end of the Soviet Union as a functioning society. That capability is not dependent on having hard-target warheads.

Opponents of hard-target capability also argue that an increase in that capability would not contribute to the deterrence of a limited Soviet strike. They reason that the Soviet Union is already deterred from launching a limited first strike because the risk of such a strike--namely, that it would start a nuclear war that would result in extensive damage to the Soviet Union--outweighs the potential military benefits. Consider, for example, the case of a limited Soviet first strike on U.S. ICBMs (in all other limited attacks on other targets, U.S. hard-target capability on MX and Minuteman ICBMs would survive for use in limited retaliatory options). Even if the Soviet attack destroyed all the U.S. ICBMs, the United States would still have roughly 5,000 SLBM warheads with which to retaliate against targets in the Soviet Union. Moreover, such an attack by the Soviet Union, which might require the detonation of nuclear warheads with a collective yield equivalent to between 65,000 and 80,000 times the yield of the nuclear bomb detonated over Hiroshima, would immediately kill 100,000 to 200,000 people in the United States. 17/ Radioactive fallout eventually would kill millions more. 18/ Given this level of damage, it is doubtful that Soviet leaders would discount the possibility that the United States would retaliate after such an attack.

Opponents further argue that an expansion of hard-target capability is not needed to support the objectives stated in NSDM-242. As noted above, NSDM-242 is a U.S. planning document that concludes that the ability to retaliate against Soviet cities is inadequate to deter a limited Soviet strike or, in the event of nuclear war, to control escalation; to achieve these two objectives the United States needs retaliatory options against limited sets of nonurban facilities valued by the Soviet Union. Opponents of increasing hard-target capability argue, however, that the United States already has such options because of its ability to conduct limited strikes against many valuable soft targets other than Soviet cities including Soviet military bases, highways, railroads, pipelines, airfields, support centers for mobile missiles, electric power centers, oil fields, and other remote industrial sites.

Indeed, an expansion of hard-target capability could even undermine NSDM-242's second objective of employing a limited retaliatory strike, if nuclear war should occur, to limit escalation. An attack on Soviet ICBMs would entail a significant risk that the Soviet Union would launch their remaining ICBMs upon warning of the U.S. attack, greatly expanding the size of the war. Attacking Soviet command and control facilities would greatly complicate efforts to negotiate an end to the conflict.

The growth in U.S. hard-target capability, particularly if deployed on submarines, might in fact increase the likelihood of a crisis turning into a war rather than decrease it, as hard-target advocates believe. From the Soviet perspective, hard-target warheads are more threatening if based on SLBMs than on ICBMs; U.S. submarines can be deployed nearer to the Soviet Union, reducing the time between detection and arrival of an attack. Furthermore, if the United States has enough prompt hard-target capability to

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17. The estimate of collective yield is based on an attack by two SS-18 (Mod 4) warheads against each of the 1,000 ICBM silos in the United States. For estimates of deaths, see William Daugherty, Barbara Levi, and Frank von Hippel, "The Consequences of "Limited" Nuclear Attacks on the United States," *International Security* (Spring 1986), p. 36.

18. It is commonly postulated that an attack on a silo with one or two nuclear weapons would include at least one surface burst to maximize the size of the crater and the amount of shock transmitted through the ground. Such surface bursts, however, result in high amounts of radioactive fallout as debris scoured from the ground falls back to earth downwind, exposing humans to significant radioactivity and contaminating soil and water in large areas of the country.

attack and destroy a high percentage of the Soviet strategic facilities, the Soviet Union would have to assume that the United States might consider employing that capability in a first strike. To counter this threat, the Soviet Union might be more likely during a crisis to prepare to launch their ICBMs upon warning of an attack. Such a "launch-on-warning" policy, in which procedures for double-checking evidence of an attack and for authorizing the launch of ICBMs are minimized, might increase the chance of an unauthorized launch or a launch based on incorrect information.

Hard-target warheads could decrease crisis stability in other ways as well. If Soviet silo-based ICBMs are more vulnerable, Soviet leaders might be more likely during a crisis to implement measures to increase the survivability of other Soviet strategic forces, possibly increasing the level of tension or hostilities. Such measures might include earlier dispersion of strategic bombers or mobile missiles, which would increase U.S. concerns of a pending Soviet attack. The Soviet Union might also take more aggressive actions such as seeking to blind U.S. satellite-borne sensors or responding more forcefully to attacks on Soviet submarines carrying SLBMs. 19/ All these measures could increase the chance that a crisis might escalate to nuclear war.

Nor is it obvious, argue opponents of expanded U.S. prompt hard-target capability, that stability would be increased if U.S. prompt hard-target warheads cause Soviet leaders to place greater emphasis on mobile nuclear forces. Stability should be enhanced if a nation has well-protected weapon systems, resulting in little incentive either for a potential aggressor to attack or for the defender to launch on warning of an attack. Mobile systems are generally protected by their ability to change locations and thus escape detection. But the Soviet Union has already protected its ICBMs with hard silos. Developing the capability to destroy these silos to encourage Soviet leaders to adopt a new survivable basing system would simply exchange one relatively stable situation for another while fueling the arms race. Furthermore, argue opponents, the United States might find that the remodeled Soviet force structure would have some undesirable features. First, Soviet leaders might choose to deploy new mobile systems without dismantling all its ICBMs in silos, leaving the possibility that they might employ a launch-on-warning policy during a crisis to protect the silos from U.S. prompt hard-target warheads. Second, mobile missiles might be inherently difficult to count, complicating verification of future force limits.

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19. The U.S. Navy has stated that the United States would seek to destroy Soviet submarines carrying SLBMs if the United States and the Soviet Union were engaged in a conventional conflict.

Finally, opponents of hard-target capability do not believe that the deployment of hard-target capability is the inevitable result of improving technology. For example, the United States could limit the hard-target capability of more accurate missiles by decreasing the yield of the warheads. 20/ Such missiles would have several advantages. The lower yield of the warheads in combination with improved accuracy would decrease collateral damage--that is, unintended damage to facilities and urban areas near the intended target. Also, since warheads of lower yield would also weigh less, the United States could increase the range of a missile, put more warheads on a missile, or devote more of a missile's payload to devices that ensure that the warheads would penetrate Soviet defenses.

Therefore, conclude opponents, the deployment of additional U.S. prompt hard-target capability would not serve U.S. national interests. Rather, it would fuel another round in the arms race while decreasing nuclear stability. If the United States is threatened by the current Soviet lead in hard-target capability, they argue, the best response is not to mimic the Soviets but to decrease the vulnerability of U.S. weapon systems and command and control facilities, as is currently being done.

Important arguments clearly exist both for and against expanding hard-target capability. The Administration's position on this issue is, however, unambiguous. It believes that expanding that capability is necessary and plans to deploy the Trident II missile accordingly.

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20. If warheads with a yield of 25 kt were deployed on the Trident II, the SSKP of the warheads would be comparable to the SSKP of the 100-kt Mark 4 warhead on the Trident I missile.

Finally, opponents of hard-target capability do not believe that the deployment of hard-target capability is the inevitable result of improved technology. For example, the United States could limit the hard-target capability of more accurate missiles by decreasing the yield of the warheads.[12] Such missiles would have several advantages. The lower yield of the warheads in combination with improved accuracy would decrease collateral damage—that is, unintended damage to civilian areas near the intended target. Also, since warheads of lower yield would also weigh less, the United States could increase the range of a missile, put more warheads on a missile, and/or use more decoys and penetration aids to ensure that the warheads could penetrate Soviet defenses.

Therefore, conclude opponents, the deployment of additional U.S. prompt hard-target capability would not serve U.S. national interests. Rather, it would threaten the Soviet Union while decreasing nuclear stability. If the United States is threatened by the current Soviet hard-target capability, they argue, the best response is not to match the Soviet ability to [illegible] the vulnerability of U.S. weapons and command and control [illegible] hard-target [illegible].

Important arguments clearly exist both for and against expanding hard-target capability. The administration's position on this issue, however, is unambiguous. It believes that acquiring this capability is necessary and plans to deploy the Trident II missile accordingly.

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[12] [illegible] warheads with a yield of [illegible] were deployed on the Trident II, the SSKP of the [illegible] warheads would be comparable to the SSKP of the 100-kt Mark 4 warhead on the Trident I missile.

CHAPTER III

ANALYSIS OF THE ADMINISTRATION'S PLAN AND ALTERNATIVES

Over the next 15 years, the largest change proposed by the Administration in the U.S. ballistic missile forces will be the replacement of Poseidon and Trident I SLBMs with Trident II SLBMs (see Figure 7). Trident I missiles currently are carried on 12 Poseidon submarines and seven Trident submarines. Trident I missiles will also be deployed on the eighth Trident submarine, which is currently on sea trials. By the year 2000, however, all Trident I missiles would be retired and Trident II missiles would be deployed on 20 Trident submarines. [1] The first eight Trident submarines would be backfitted with Trident II missiles when they are overhauled approximately 10 years after initial deployment. The Trident II would be deployed as original equipment on the ninth through twentieth Trident submarines beginning in fiscal year 1990.

The Trident II missiles deployed on these 20 submarines would carry approximately 4,800 nuclear warheads, each with a significant capability to destroy a hardened target. These warheads, in combination with ICBM warheads, would give the United States about 6,800 deployed prompt hard-target warheads. This increase would represent a fundamental shift in U.S. capability, enabling the United States to conduct large-scale attacks on hardened targets in the Soviet Union.

CBO ASSUMPTIONS

To evaluate both the Administration's plan to deploy the Trident II and alternatives to that plan, several assumptions must be made about Trident II missiles and other missiles in the U.S. inventory. First, as noted in Chapter I, a Trident II missile could carry about 11 to 13 Mark 4 warheads or six to nine Mark 5 warheads to a range comparable to that of the Trident I missile, or it could carry fewer Mark 4 or Mark 5 warheads to a greater range. The Congressional Budget Office (CBO) assumed that the Navy

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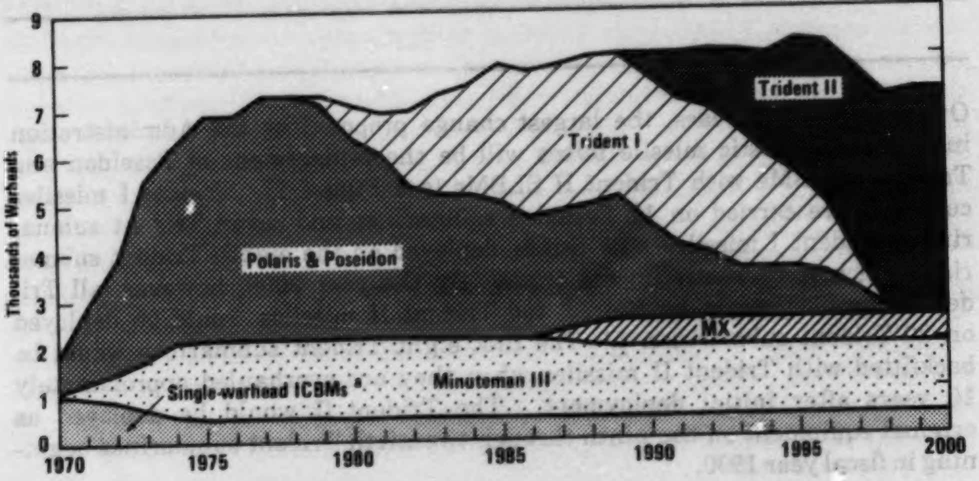
[1] The Navy has not stated whether it will seek more than 20 Trident submarines. The Navy is using 20 Trident submarines, however, as the planning figure for the design of base facilities.

Figure 7.
Number of U.S. Ballistic Missile Warheads, Historically and Under the Administration's Plan, Fiscal Years 1970-2000



SOURCE: Congressional Budget Office.

a Includes Titan II, Minuteman I, and Minuteman II.

would choose to emphasize payload over range and that, for the purpose of illustrating force capabilities, the Trident II would carry either 12 Mark 4 warheads or eight Mark 5 warheads. (Twelve and eight are the midpoints of the intervals noted above, rounded to the nearest integer.)

The capability of the U.S. Trident II force would also depend on the mix of Trident II missiles deployed with the smaller Mark 4 warheads rather than Mark 5 warheads. For the purpose of comparing options, CBO assumed that half of the missiles would carry the Mark 4 and half would carry the Mark 5. 2/ This ratio has a significant effect on the capability of the Trident II missile force because the Trident II is more effective against soft targets if deployed with the larger number of Mark 4 warheads but is more effective against very hard targets if deployed with Mark 5 warheads. The effects of varying this ratio, which Congress might choose to consider, are presented in Appendix B.

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2. The Navy's final plan for the mix of Trident II missiles with Mark 4 warheads and Trident II missiles with Mark 5 warheads will probably depend on the missions assigned to the Trident II in the future.

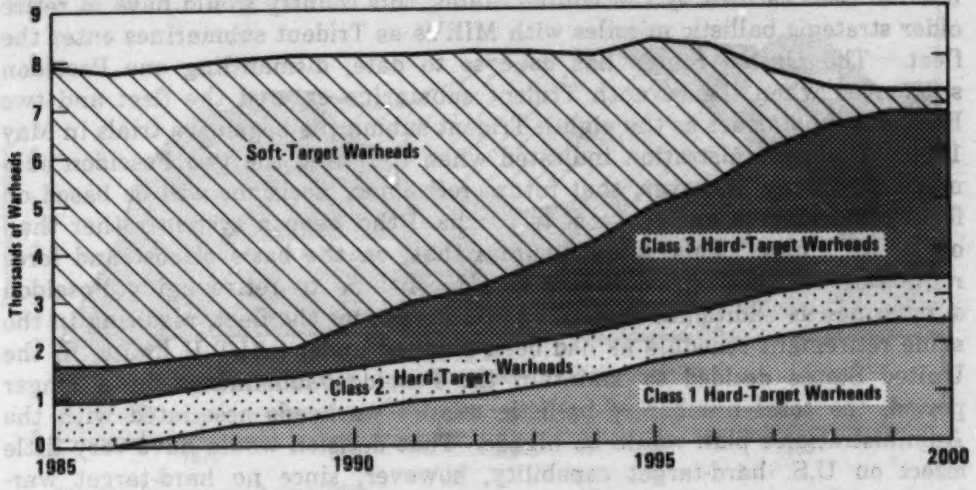
The capability of U.S. strategic ballistic missiles under the Administration's plan and the alternatives presented in this study would also depend on which older missiles the United States chooses to retire. Under the limits of the SALT II agreement (Strategic Arms Limitation Talks), which has not been ratified by the United States, this country would have to retire older strategic ballistic missiles with MIRVs as Trident submarines enter the fleet. The United States has done so to date, dismantling one Poseidon submarine when the seventh Trident submarine entered the fleet and two Poseidon submarines as the eighth Trident submarine began sea trials in May 1986. The Administration indicated when it retired the two Poseidon submarines in May, however, that future retirement decisions will be based on force requirements and the cost to overhaul the weapon system rather than on SALT limits. This study assumes that, on the basis of cost and force requirements, the United States would continue to retire aging Poseidon submarines as additional Trident submarines enter the fleet, resulting in the same retirement schedule as had been planned under SALT II limits. If the United States decided to maintain the Poseidon submarines for a longer period, the total number of ballistic missile warheads associated with the Administration's plan would be higher. That decision would have very little effect on U.S. hard-target capability, however, since no hard-target warheads are deployed on Poseidon submarines.

Finally, U.S. prompt hard-target capability under the Administration's plan and the alternatives would be affected by the procurement of additional ICBMs. This study assumes that although the Administration is requesting that the Congress approve deployment of an additional 50 MX missiles, for a total of 100 deployed MX missiles, only 50 MX missiles would be deployed as currently approved by the Congress. Also, although the Administration is considering the procurement of a small mobile ICBM carrying one to three warheads, that missile has not been included in the Administration's plan in this study since its characteristics and the number to be procured have not yet been determined.

THE ADMINISTRATION'S PLAN

The Administration's plan to deploy 20 Trident submarines equipped with Trident II missiles by the year 2000 would greatly expand U.S. prompt hard-target capability. Between 1986 and the year 2000, given the assumptions noted above, the number of Class 1 ballistic missile warheads deployed by the United States would grow from zero to more than 2,400--about 80 per-

Figure 8.
Number of U.S. Ballistic Missile Warheads, by Class, Under the Administration's Plan, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTE: Warheads are classified here by their Single Shot Kill Probability (SSKP)—the probability that an arriving warhead will destroy a target of given hardness. Class 1 warheads have an SSKP of at least 70 percent against a 5,000-psi target. Class 2 warheads do not meet that standard but have an SSKP of at least 70 percent against a 2,000-psi target. Class 3 warheads do not meet either of those standards but have an SSKP of at least 70 percent against a 500-psi target. All other warheads are soft-target warheads.

cent of which would be Mark 5 warheads on Trident II missiles (see Figure 8). The number of Class 2 ballistic missile warheads would remain constant during that period at 900 warheads. The number of Class 3 ballistic missile warheads would grow from 750 to about 3,500, more than 80 percent of which would be Mark 4 warheads on Trident II missiles. As the number of hard-target warheads on ballistic missiles increases, the number of soft-target warheads on ballistic missiles would correspondingly decline--from about 6,100 in 1986 to less than 500 in the year 2000. The total number of ballistic missile warheads would therefore be largely unchanged.

Effect on Capability

Measures of capability against two hypothetical sets of hardened targets--a large set of 2,000 facilities and a small set of 500 facilities--also reflect the large contribution that the Trident II missile would make to U.S. prompt hard-target capability under the Administration's plan. With the current (1986) inventory of ICBMs and SLBMs, the United States could destroy 59 percent of the large target set hardened to 2,000 psi and 42 percent of the large set hardened to 5,000 psi (see Figure 9). 3/ By the year 2000, these percentages would increase to 90 percent and 81 percent, respectively.

Following an effective attack on U.S. silo-based ICBMs, however, the capability of U.S. forces to retaliate would be reduced. It is therefore useful to assess the capability of U.S. SLBMs--most of which would be expected to survive a Soviet attack--independently from U.S. ICBMs (see Figure 10). In 1986, U.S. SLBMs could destroy 28 percent of the target set hardened to 2,000 psi and 17 percent of the set hardened to 5,000 psi. By the year 2000, the percentage of targets destroyed would have increased to 85 percent and 73 percent, respectively. Thus, as more Trident II missiles were deployed, the absence of ICBMs (including the MX ICBM) would have a decreasing effect on U.S. prompt hard-target capability.

The effectiveness of the U.S. prompt hard-target warheads also would depend on the size of the time-urgent target set against which they were directed. The size of that target set would depend in turn on the missions envisioned for these warheads. As discussed in Chapter II, some proponents of expanded U.S. hard-target capability argue that it is important to provide U.S. leaders with a wider range of options, possibly including the ability to attack promptly the entire set of strategic targets in the Soviet Union. In that situation, the target set could include about 2,000 sites as evaluated in Figures 9 and 10. Other proponents of expanded hard-target capability, however, believe that U.S. ability to retaliate with prompt hard-target warheads against a smaller target set would fulfill U.S. national security objectives, including the primary objective of enhancing deterrence. Figure 11 accordingly illustrates the capability of U.S. SLBM warheads against a much smaller target set of 500 hardened facilities. Against this target set, the first four Trident submarines deployed with Trident II missiles would greatly increase U.S. capability, while missiles on subsequent submarines would have less of an impact.

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3. The precise results of CBO's calculations are given for the purpose of comparing performance over a span of years and among the various plans. They should be used for comparative purposes only because many assumptions cannot be established with certainty. For example, many of the point estimates that are required for these calculations--including missile system reliability and warhead accuracy--are chosen from a distribution of potentially correct values.

Figure 9.
Administration's Plan: Performance of U.S. ICBMs and SLBMs Against a Large Target Set, Fiscal Years 1985-2000

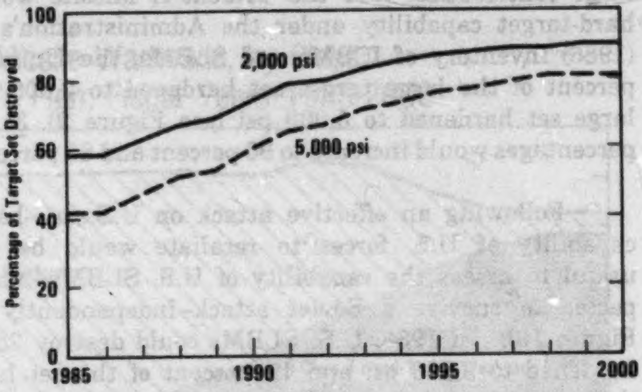


Figure 10.
Administration's Plan: Performance of U.S. SLBMs Against a Large Target Set, Fiscal Years 1985-2000

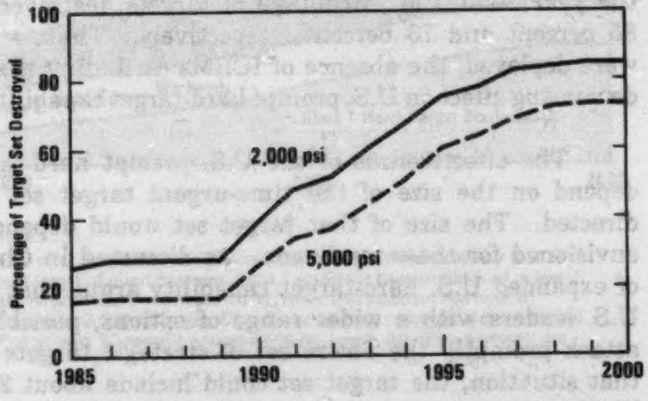
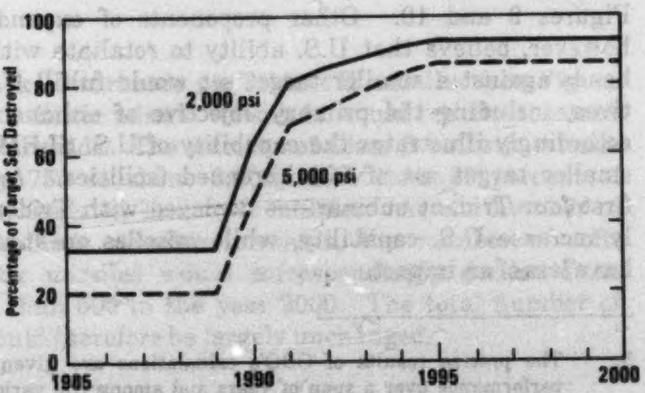


Figure 11.
Administration's Plan: Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTES: A large target set (Figures 9 and 10) is 2,000 facilities; a small target set (Figure 11) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 2,000 psi and 5,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed.

Effect on Costs

To provide the Trident II missiles required for flight tests and deployment on 20 submarines, the Administration currently plans to procure 844 missiles over 13 years. The cost in fiscal year 1987--for ongoing research and development and procurement of the first 21 missiles--would be $3.1 billion, of which $1.6 billion is for research and development. The cost in fiscal year 1987 dollars over the first five years of the program, during which 291 missiles would be procured, would be $13.4 billion. During that period, research and development of the missile would be completed at a cost of $3.4 billion. Finally, the total cost of development and procurement of the missile (fiscal years 1987 through 1999) would be about $26.1 billion (see Table 4). Although all budget figures in this paper are in fiscal year 1987 dollars, Table 4 also includes total program costs for the Administration's plan in discounted dollars to portray the real cost in current resources of different options pursued over long periods of time. [4]

Procurement of the Trident II missile, however, would account for only a portion of the cost of the Administration's plan. It would be necessary to operate Poseidon submarines until they are replaced by Trident submarines and to flight-test Trident I missiles until they are replaced by Trident II missiles. In addition, the first eight Trident submarines would have to be modified to carry the Trident II rather than the Trident I missile at a cost of about $305 million for the first submarine and $225 million for each of the remaining seven submarines. Modifications would include replacing existing launch tubes with larger launch tubes and substituting a more powerful gas ejection system. Numerous support systems, such as the navigation and fire control subsystems, also would have to be changed. In addition to these changes, seven more Trident submarines would have to be procured (funds for the fourteenth have been requested in fiscal year 1987), and all 20 Trident submarines would have to be operated over their approximately 35-year life span. Finally, to uncover and correct problems in the Trident II missiles and to update operational parameters for the Single Integrated Operational Plan (the nation's blueprint for conducting nuclear war), 352 Trident II flight

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[4] Discounting is a way to calculate, in today's dollars, the value of a future expenditure or a stream of future annual expenditures. The result is called present value. A future expenditure is discounted to its present value with the following formula:

$$\text{Present Value} = \text{Future Value}/(1 + i)^n$$

In this formula, "n" is the number of years between the present year and the year in which the expenditure is made, and "i" is the discount rate. Future value is in fiscal year 1987 dollars. The discount rate used in this analysis is 4 percent in real terms.

TABLE 4. PROCUREMENT AND COSTS FOR THE ADMINISTRATION'S TRIDENT II PROGRAM AND ALTERNATIVES
(By fiscal year in billions of 1987 dollars of budget authority)

Number of Missiles Procured and Costs	1987	1988	1989	1990	1991	Total 1987-1991	Total Program (1987-2030)	Total Program in Discounted Dollars a/
Administration's Plan								
Trident II Missiles	21	66	66	66	72	291	844	--
Costs								
Investment b/	3.1	3.3	2.8	2.4	1.8	13.4	26.1	21.7
Other c/	4.3	4.3	4.4	4.3	4.4	21.7	78.5	49.3
Total	7.4	7.6	7.2	6.7	6.2	35.1	104.6	71.0
Alternative 1: Cancel Backfits								
Trident II Missiles	21	66	66	66	72	291	660	--
Costs								
Investment b/	3.1	3.3	2.8	2.4	1.8	13.4	21.5	18.7
Other c/	4.3	4.3	4.2	4.2	4.2	21.2	77.8	48.6
Total	7.4	7.6	7.0	6.6	6.0	34.6	99.3	67.3
Savings from Admin. plan	d/	d/	0.2	0.1	0.2	0.5	5.3	3.6
Alternative 2: Reduce and Delay Procurement of Trident II Missiles								
Trident II Missiles	0	0	0	35	72	107	516	--
Costs								
Investment b/	2.1	2.1	2.5	2.3	2.5	11.5	22.8	19.2
Other c/	4.9	4.7	4.2	4.2	4.2	22.2	78.9	49.6
Total	7.0	6.8	6.7	6.5	6.7	33.7	101.7	68.8
Savings from Admin. plan	0.4	0.8	0.5	0.2	(-0.5)	1.4	2.9	2.2
Alternative 3: Cancel Trident II Program								
Trident I Missiles	0	0	0	25	60	85	395	--
Costs								
Investment b/	2.1	2.1	2.4	2.2	1.8	10.6	16.4	14.3
Other c/	4.9	4.7	4.4	4.3	4.2	20.5	78.6	49.5
Total	7.0	6.8	6.8	6.5	6.0	33.1	95.0	63.8
Savings from Admin. plan	0.4	0.8	0.4	0.2	0.2	2.0	9.6	7.2

SOURCE: Congressional Budget Office.

NOTE: Budget figures do not include the cost of procuring ballistic missile warheads. These costs, which are paid by the Department of Energy, are classified.

a. The discount rate is 4 percent. Discounting converts a stream of future dollar amounts to their value in an earlier year, reflecting the notion that a dollar held in the future is worth less than one held today. Discounted dollars are a better measure of the cost in current resources of an expenditure stream over an extended period.

b. Includes research and development, procurement, and military construction for the Trident missiles.

c. Includes operating and support costs for the Trident and Poseidon submarines; flight tests for Trident I and Trident II missiles; procurement of Trident submarines; converting the first eight Trident submarines to carry Trident II missiles (if applicable); and converting submarines under construction to carry Trident I missiles (if applicable).

d. Savings in fiscal year 1987 would be $2.5 million; in fiscal year 1988, $63 million.

tests are planned. These tasks would raise the total program cost for fiscal years 1987 through 2030, when the Trident force would be largely retired, to about $105 billion.

While the costs of deploying SLBMs under the Administration's plan are substantial, they account for less than a third of the total U.S. budget for strategic forces. Which programs should be included in that budget is often debated. By the Department of Defense's definition, however, the proposed fiscal year 1987 budget for strategic forces is $25.4 billion, rising to $29.7 billion (current year dollars) by 1989. As a percentage of the total strategic budget proposed by the Administration, budget authority for the Trident II missile and associated costs detailed above would range from 29 percent in fiscal year 1987 to 25 percent in fiscal year 1989.

The Administration's plan for the Trident II missile would involve substantial costs and a dramatic expansion of U.S. prompt hard-target capability. If the Congress wishes to hold down costs or slow the growth of hard-target capability, the Administration's plan could be modified in several ways. Alternatives considered in this study include not backfitting the Trident II missile into the first eight Trident submarines, and reducing and delaying procurement of the Trident II missile such that it is deployed only on the last eight Trident submarines. A third option would be to cancel the Trident II program and deploy only the Trident I missile on all 20 Trident submarines.

ALTERNATIVE I: CANCEL PLAN TO BACKFIT TRIDENT SUBMARINES WITH TRIDENT II MISSILES

This alternative would eliminate the current plan to backfit the eight Trident submarines, which are currently designed to carry Trident I missiles, with Trident II missiles. Only the last 12 of the 20 Trident submarines would be deployed with Trident II missiles, reducing Trident II procurement from 844 missiles under the Administration's plan to 660. 5/

To support the extended deployment of the Trident I missile, its flight-test program would be continued until the year 2012. Although that

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5. Since in some years a maximum of 12 submarines would be deployed with Trident II missiles rather than 19 submarines as under the Administration's plan (of the 20 Trident submarines, one would always be undergoing an overhaul), seven fewer shiploads of missiles would have to be procured. In addition, the Demonstration and Shakedown Operations (DASO) program would be reduced by 16 missiles. Trident II procurement therefore would be reduced by 184 missiles ((7 x 24) + 16 = 184 missiles).

extended test program would require 146 Trident I missiles, no additional Trident I missiles would have to be procured; rather, the increased demand would be met by Trident I missiles currently in the stockpile or deployed aboard Poseidon submarines scheduled for retirement.

In other respects, this alternative is identical to the Administration's plan. Although the first backfit of a Trident submarine with Trident II missiles is not scheduled until 1991, the Congress could indicate its intention to pursue this option by deleting $2.5 million in fiscal year 1987 budget authority, which is designated to provide advance planning and to begin procurement of long-lead items for converting the eight submarines.

Effect on Capability

Although the United States would have fewer hard-target warheads in the year 2000 with this option than under the Administration's plan, this lower level of capability would have only a small effect on the U.S. ability to conduct retaliatory strikes on either large or small sets of time-urgent hardened targets in the Soviet Union.

Under this alternative, in the year 2000 the United States would have about 4,880 prompt hard-target warheads rather than 6,800 as under the Administration's plan. The reduction would occur in Class 1 hard-target warheads (from 2,420 to about 1,650) and in Class 3 (from 3,480 to about 2,330). The number of Class 2 warheads would not change (see Figure 12). Deployed capability under this alternative would be the same as under the Administration's plan until 1992, when backfitted submarines would begin to enter the fleet.

The decrease in the number of U.S. prompt hard-target warheads under this option would have a small effect on their performance against target sets of hardened facilities. As in the analysis of the Administration's plan, CBO used two target sets to reflect various assumptions. If U.S. ICBMs and SLBMs were both available to attack a large set of 2,000 targets hardened to 2,000 psi, performance in the year 2000 would decrease from the destruction of 90 percent of the targets under the Administration's plan to 87 percent (see Figure 13). 6/ If only U.S. SLBMs were available, reflecting the mission of a retaliatory strike, performance against that target

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6. To simplify presentation, only the changes in capability against target sets hardened to 2,000 psi are shown here. Comparable changes occur in target sets hardened to 5,000 psi (see Appendix C).

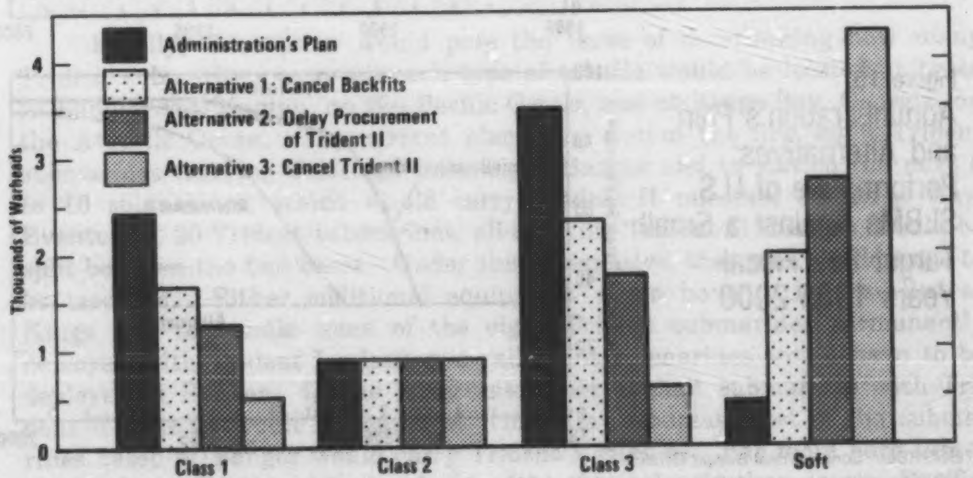
set would decrease from the destruction of 85 percent of the targets to 75 percent (see Figure 14). The performance of U.S SLBMs against a smaller set of 500 facilities, reflecting the mission of conducting a limited retaliatory strike, would be the same under this alternative and the Administration's plan (see Figure 15).

Effect on Costs

About $5.3 billion would eventually be saved under this option, reflecting procurement of 184 fewer Trident II missiles and cancellation of plans to modify the first eight Trident submarines to carry the Trident II missiles (see Table 4). These savings constitute only about 5 percent of the total cost (including procurement and operation of Trident submarines) of deploying Trident II SLBMs under the Administration's plan. In addition, savings in fiscal years 1987 and 1988 would be small; the only change in those years would be the elimination of funds for planning and for procuring long-lead items to modify the eight Trident submarines.

Figure 12.

Number of U.S. Ballistic Missile Warheads, by Class, in Fiscal Year 2000 Under the Administration's Plan and Alternatives



SOURCE: Congressional Budget Office.

NOTE: Warheads are classified here by their Single Shot Kill Probability (SSKP) – the probability that an arriving warhead will destroy a target of given hardness. Class 1 warheads have an SSKP of at least 70 percent against a 5,000-psi target. Class 2 warheads do not meet that standard but have an SSKP of at least 70 percent against a 2,000-psi target. Class 3 warheads do not meet either of those standards but have an SSKP of at least 70 percent against a 500-psi target. All other warheads are soft-target warheads.

Figure 13.
Administration's Plan and Alternatives: Performance of U.S. ICBMs and SLBMs Against a Large Target Set, Fiscal Years 1985-2000

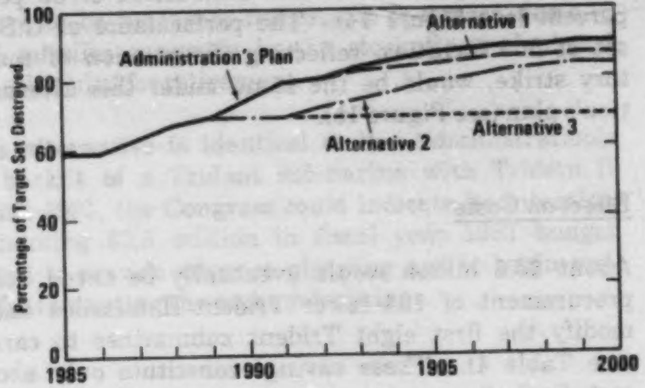


Figure 14.
Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Large Target Set, Fiscal Years 1985-2000

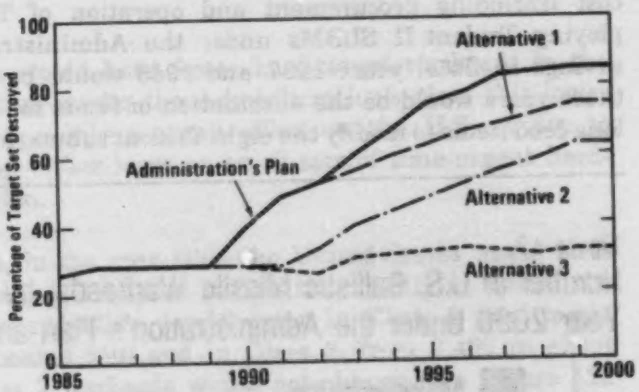
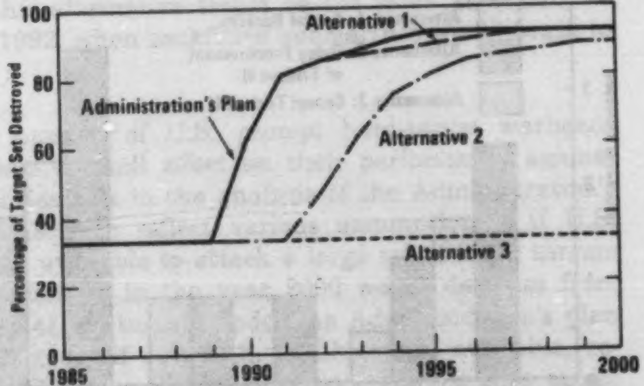


Figure 15.
Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTES: A large target set (Figures 13 and 14) is 2,000 facilities; a small target set (Figure 15) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 2,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed. Alternative 1 = Cancel Backfits; Alternative 2 = Delay Procurement of Trident II Missiles; Alternative 3 = Cancel Trident II Program.

Savings from buying fewer Trident II missiles would not be offset by the cost of buying more Trident I missiles, since the number of Trident I missiles in storage and on retiring Poseidon submarines would be sufficient to supply the eight Trident submarines and a flight-test program. Thus, this option would make fuller use of Trident I missiles already procured than would the Administration's plan.

Other Effects

A sufficient number of Trident I missiles would be available to continue flight-test programs. Specifically, the Trident I Follow-on Operational Test (FOT) program, which updates estimates of missile reliability and accuracy, could be extended through the year 2012 at eight missiles per year. This alternative also would provide for additional Trident I DASO (Demonstration and Shakedown Operations) flights. A DASO flight consists of the test flight of a single missile from a submarine that has just completed a major overhaul; this flight provides a final check of the ship's capability before the ship is deployed. If backfits were canceled, eight Trident submarines would go through two additional overhauls while carrying the Trident I missile, requiring 16 DASO flights. This alternative would also decrease the number of Trident II DASO flights by 16 missiles to reflect the reduced number of ships carrying the Trident II but would maintain the remainder of the Trident II test program at the currently planned level.

Finally, this option would pose the issue of determining how many Trident submarines carrying each type of missile would be located at bases in Bangor, Washington, on the Pacific Ocean, and at Kings Bay, Georgia, on the Atlantic Ocean. The current plan is to station the first eight Trident submarines carrying Trident I missiles at Bangor and to station the next 8 to 10 submarines, which would carry Trident II missiles, at Kings Bay. Eventually, 20 Trident submarines, all carrying Trident II missiles, would be split between the two bases. Under this alternative, that plan would have to be modified. Either additional equipment would have to be installed at Kings Bay to handle some of the eight Trident submarines permanently deployed with Trident I missiles, or all eight submarines would have to be deployed at Bangor. In the latter case, only Trident submarines with Trident II missiles would be based at Kings Bay whereas most of the submarines based at Bangor would carry Trident I missiles. Far more hard-target warheads would therefore be deployed in the Atlantic than in the Pacific, possibly causing less than an optimal allocation of warheads to targets in the Soviet Union.

This alternative is consistent with the goal of increasing hard-target capability, though it would not result in as large an increase as under the Administration's plan. Canceling backfits would reduce costs but would yield only small savings over the next few years. If higher near-term savings are to be achieved, the Trident II program would have to be delayed.

ALTERNATIVE 2: REDUCE AND DELAY PROCUREMENT OF TRIDENT II MISSILES

As in Alternative 1, this option would cancel the plan to backfit the first eight Trident submarines with Trident II missiles. In addition, Trident I missiles would be deployed on four more Trident submarines (the ninth through the twelfth), thereby maximizing the use of existing Trident I missiles and requiring procurement of only 516 Trident II missiles--328 fewer than in the Administration's plan. Deploying Trident I missiles aboard the ninth through twelfth Trident submarines would also allow a three-year delay in the procurement of Trident II missiles, resulting in larger near-term savings than with the first alternative. In the long term, however, this option would cost slightly more than the first alternative as a result of increased research and development costs for the Trident II missile.

Effect on Capability

This option would reduce the number of U.S. prompt hard-target warheads by the year 2000 by about 40 percent, and would have a significant effect on U.S. ability to retaliate with SLBMs against a large target set. It would have virtually no effect, however, on U.S. ability to retaliate with SLBMs against a small target set.

By deploying Trident II missiles aboard only eight submarines rather than 20, as in the Administration's plan, this option would greatly diminish total growth in the number of hard-target warheads. In the year 2000, the United States would have about 3,920 hard-target warheads rather than 6,800 as under the Administration's plan. [7] Of this reduction of 2,880 hard-target warheads, approximately 1,150 would be Class 1 and 1,730 would be Class 3; as under Alternative 1, the number of Class 2 warheads would not change (see Figure 12).

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[7] The number of warheads would not change, though, until 1990 when, under the Administration's plan, the ninth Trident submarine would enter service.

The decrease in the number of U.S. prompt hard-target warheads under this option would affect their performance against target sets of hardened facilities. If both ICBMs and SLBMs were available to attack a large target set of 2,000-psi facilities, performance would decrease from the destruction of 90 percent of the targets under the Administration's plan to 84 percent (see Figure 13). If only SLBMs were available, the percentage of targets destroyed would decrease from 85 percent to 63 percent (see Figure 14). Against a smaller target set, reflecting the mission of conducting a limited retaliatory strike, the performance of SLBMs would decrease from destroying 93 percent of the targets to 89 percent (see Figure 15).

Effect on Costs

Over the life of the Trident II program, this alternative would save $2.9 billion in budget authority. Savings in 1987 would amount to $0.4 billion and would total $1.4 billion over the next five years. In the near term, these savings would be greater than under Alternative 1 because procurement of the Trident II would be deferred until 1990. Long-term savings, however, would be lower because research and development costs would increase for the Trident II missile.

The major savings in this alternative come from canceling the backfit of the first eight Trident submarines and putting Trident I missiles on the ninth through the twelfth submarines, which would lower the number of Trident II missiles required by 328. 8/ These savings would not be offset by the purchase of more Trident I missiles, because missiles in storage and on retiring submarines would be used. To provide enough Trident I missiles to fill the additional four Trident submarines, five Poseidon submarines carrying the Trident I missile would have to be retired approximately three years earlier than planned. To minimize the reduction in capability caused by these early retirements, the service of Poseidon submarines carrying the Poseidon missile, which otherwise would have been retired, could be extended. 9/

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8. Since in some years a maximum of eight submarines would be deployed with Trident II missiles under this alternative rather than 19 submarines as under the Administration's plan (of the 20 Trident submarines, one would always be undergoing an overhaul), it would be necessary to procure 11 fewer shiploads of missiles. In addition, the FOT program would be delayed by three years, saving 36 missiles, and the DASO program would be reduced by 28 missiles. Therefore, Trident II procurement would be reduced by 328 missiles ((11 x 24) + 36 + 28 = 328 missiles).

9. The extended service of the Poseidon submarines would not include deploying them beyond the period that they can operate without a major overhaul.

Although this alternative would not require procurement of additional Trident I missiles, it would have significant costs that partially offset savings. Most important, funding for the Trident II program would have to be continued to keep a design and manufacturing team together until procurement begins in 1990. That would add about $3.5 billion to the cost of the Trident II missile program. In addition, the Navy either would have to modify facilities at Bangor, Washington, to handle 12 rather than 10 Trident submarines carrying Trident I missiles, or it would have to modify the base at Kings Bay to handle Trident I missiles. The Navy also would have to reconfigure the ninth through twelfth Trident submarines, which are currently under construction, with equipment designed for the Trident I missile. These changes would include a smaller launch tube, a different gas ejection system, and the modification or replacement of electrical subsystems that interface with the missile, such as the fire control system and the navigation system. 10/ Although a detailed engineering study would be required to refine modification plans and cost estimates, the Navy currently estimates that the changes will cost roughly $250 million for each of the four submarines. 11/

This alternative would employ the existing inventory of Trident I missiles more efficiently than the previous alternative by increasing and prolonging deployments, but would decrease the efficiency of the Trident II program because the delay would add to research costs. The latter effect outweighs the former, resulting in lower long-term savings than under Alternative 1.

Other Effects

By deploying four more Trident submarines with Trident I missiles and delaying Trident II procurement, this option would allow the Congress more time to assess the Trident II program in light of fiscal constraints and questions about the need for hard-target capability. The time required to procure and install the equipment to deploy the Trident I missile on those four

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10. Since the Trident I missile is much lighter than the Trident II missile, a different gas ejection system is required to propel it to the surface at the proper speed.

11. The ninth submarine is almost ready to be launched. Some weapon subsystems, however, will be fitted into the submarine after it is in the water. The subsequent submarines are less complete but are receiving more equipment at earlier stages in construction. Therefore, a different engineering plan would have to be developed for each submarine. It is not evident at this point how much less expensive it would be to convert the twelfth submarine than to convert the ninth. Consequently, the full conversion price supplied by the Navy has been applied to all four submarines.

additional Trident submarines, however, would probably delay deployment of each submarine by up to two years. These delays would be compensated for by keeping the Poseidon ships with Trident I missiles at sea longer, resulting in little impact on the capability of the ballistic missile fleet.

As in the previous alternative, the Trident I FOT flight-test program would continue through the year 2012 to support extended deployment of Trident I missiles. Since fewer missiles would be available for testing as a result of the larger number that are deployed, however, the number of flight tests would have to be limited to six per year. This lower level of testing would meet the minimum requirement established by the Joint Chiefs of Staff and would have little effect on estimates of the missile's accuracy and reliability. It would have some effect, however, on the time required to detect and correct emerging problems. 12/ Also, most DASO flights for the Trident I would have to come at the expense of the FOT program.

Limits on Trident I testing could, of course, be avoided if the Administration purchased more Trident I missiles. The production line for these missiles has been closed, however, and--as the next alternative makes clear --reopening the line would be too expensive for purchasing test missiles alone.

ALTERNATIVE 3: CANCEL THE TRIDENT II PROGRAM

Canceling the Trident II program would mean that no further development or production would be funded beyond 1986. The Trident I production line would be reopened in 1990 to provide enough Trident I missiles to fill 20 Trident submarines and to conduct a flight-test program at the level cur-

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12. If an estimate of missile reliability were based on test results from a single year, there would be a high expected error in the estimate because of the small size of the data base. Therefore, the Navy estimates reliability on the basis of all relevant flight-test data. With that methodology, decreasing the number of annual flight tests from eight (as in Alternative 1) to six would increase the expected error in the estimate of reliability by less than one percentage point. The decrease from eight tests per year to six tests per year would increase the expected error in the estimate of CEP employed in the Strategic Integrated Operational Plan (SIOP) by less than three feet. That change is not significant enough to affect either the missions assigned to the missile or calculations of expected damage. The average number of months required to detect an emerging problem would increase from a level of 4 to 15 months in Alternative 1 (the range reflects differing assumptions about the value of information from inspections and component tests) to 5 to 20 months under Alternative 2. See Congressional Budget Office, "Trident II Missile Test Program" (Staff Working Paper, February 1986).

rently planned for the Trident II missile. An additional 395 Trident I missiles would have to be procured.

Effect on Capability

By canceling the Trident II missile program and thus eliminating the deployment of hard-target warheads on submarines, this option would substantially reduce U.S. ability to conduct retaliatory strikes on either large or small sets of time-urgent hardened targets in the Soviet Union.

Under this alternative, the only growth in the U.S. inventory of prompt hard-target warheads would result from the deployment of 500 warheads on 50 MX missiles. Thus, by the year 2000, the United States would have only 2,000 prompt hard-target warheads (1,500 Minuteman III warheads in addition to 500 MX warheads) instead of the 6,800 warheads under the Administration's plan.

The decrease in the number of U.S. prompt hard-target warheads under this option would have a larger effect on performance against target sets of hardened facilities than under the other two alternatives. If U.S. ICBMs and SLBMs were both available to attack a set of 2,000 facilities hardened to 2,000 psi, performance would decrease from the destruction of 90 percent of the targets under the Administration's plan to 69 percent (see Figure 13). If only SLBMs were available, 32 percent of the targets would be destroyed, compared with 84 percent under the Administration's plan (see Figure 14). If the performance of only U.S. SLBMs is weighed against a smaller target set, performance would decrease from 93 percent under the Administration's plan to 33 percent (see Figure 15). 13/

Proponents of hard-target capability might view this alternative as diminishing U.S. ability to deter a limited strike or, should nuclear war begin, to conduct a limited strike best suited to U.S. political and military objectives. To opponents of increased hard-target capability, however, this decrease would neither weaken U.S. deterrence nor affect limited retaliatory options that are compatible with the objective of controlling escalation. Furthermore, opponents would argue, this decrease in capability would lower the probability that a crisis would escalate to nuclear war.

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13. If the United States proceeds to procure and deploy small mobile ICBMs with hard-target capability, these ICBMs would considerably improve U.S. ability to conduct retaliatory strikes against time-urgent hardened targets under this option.

Effect on Cost

This alternative would save between $9.6 billion and $11.3 billion in budget authority, depending on the cost of reopening the Trident I production line. On the basis of the lower figure, savings would amount to $0.4 billion in 1987 and would total $2.0 billion over the next five years. On the basis of the higher savings figure, an additional $1.7 billion in savings would accrue between 1987 and 1990.

As in Alternative 2, these savings are the net result of decreases and partially offsetting increases in costs. On the one hand, this alternative would generate significant savings by canceling the production of 844 Trident II missiles, the Trident II missile test program, and the modification of the first eight Trident submarines to enable them to carry Trident II missiles. On the other hand, increased costs described in Alternative 2 would be incurred. The Navy would have to modify the Trident submarines currently under construction to carry the Trident I missile rather than the Trident II. 14/ Also, a delay of up to two years would occur in deploying those submarines and would have to be compensated for by extending the deployment of Poseidon submarines.

More important, and unique to this option, is the reopening of the Trident I missile line. Reopening the line would require requalifying contractors, refurbishing and replacing tooling, redesigning parts for which the original materials are unavailable, and testing the new parts to ensure that the performance characteristics match those of the original parts. In addition, the submarine port at Kings Bay, Georgia, would have to be modified to handle the Trident I rather than the Trident II. These activities would cost between $3.5 billion and $5.2 billion. Finally, procuring the additional 395 Trident I missiles would cost about $11 billion.

Other Effects

This alternative, in contrast to the previous one, could maintain the test program for the Trident I missile at levels currently planned for the Trident II because, with a new production line open, additional Trident I mis-

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14. Whereas in Alternative 1 (which called for the deployment of 12 submarines with Trident I missiles) it would be necessary to modify four of the five Trident submarines under construction, in this alternative all five (the ninth through the thirteenth) would have to be modified. The fourteenth Trident submarine, for which the Administration has requested funding in fiscal year 1987, would be built from the beginning to carry the Trident I missile.

siles could be purchased. Specifically, the FOT program would be set at 12 missiles per year for 1990 through 2012. The DASO program would be increased by 52 missiles so that every new or overhauled Trident submarine would be able to launch a missile before becoming operational. Also, the Fleet Return Evaluation Program (FREP) would be maintained at 30 missiles, the level currently planned for the Trident II program. 15/

Finally, if the Trident II program were canceled, the United States would not be able to provide Trident II missiles to the United Kingdom, which is beginning construction of the first of four submarines designed to accommodate 16 Trident II missiles each. Consequently, the United Kingdom would have to modify plans for the submarines so that they would carry Trident I rather than Trident II missiles.

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15. The FREP program provides a reserve so that enough missiles will be available for scheduled deployments even though some missiles are being transported, dismantled, inspected, or reassembled. Missiles are likely to be in one of those conditions as a result of two procedures. First, the Navy regularly removes a deployed missile from a submarine to examine it for signs of deterioration. These missiles--called Service Life Evaluation (SLE) missiles--are not destroyed. Following ground-based inspections and tests, the components reenter the parts inventory and are incorporated into new or refurbished missiles as required. Second, when a submarine undergoes a major overhaul, all the missiles on that submarine are dismantled. As with SLE missiles, the components reenter the parts inventory following inspection and, if needed, repair.

APPENDIXES

METHOD USED TO CALCULATE SSKP

The probability that a warhead will destroy a target is a function of reliability (the probability that the warhead will arrive at the target and detonate) and the Single Shot Kill Probability (SSKP)--the probability that the arriving warhead will destroy the target. The SSKP of a warhead depends on the hardness of a target and on the warhead's yield and accuracy. Yield affects the SSKP because a weapon of higher yield produces, at any given radius from the blast, a higher peak overpressure (pressure above standard atmospheric pressure) and a longer period of high overpressure. Both a higher peak overpressure and a longer period of high overpressure increase the probability that a structure will suffer major structural damage from a blast. Better accuracy reduces the distance between the target and the blast.

The method used in this study to calculate the SSKP was developed by the Defense Nuclear Agency (DNA). This method employs an index of target hardness, called a vulnerability or "V" number. The index is pegged to a reference yield of 20 kilotons (kt), which is a simple way to make the duration of the period of high overpressure a function of the peak overpressure generated by a blast. Thus, each target is given a V number based on the level of peak overpressure (generated by a 20-kt blast) at which the target has a 50 percent probability of suffering major structural damage.

Public statements by the Department of Defense on the hardness of targets, however, are given in terms of pounds per square inch (psi) of peak overpressure rather than in terms of a V number. The hardness (H) in pounds per square inch can be converted to a V number with the following formula: 1/

V = (5.456 x ln(H)) + 4.89

1/ This formula can be derived by inserting yield (Y = [illegible] kt) and the k-factor (K = 0) into the following set of formulas:

1) a = 1.15
2) b = [illegible]

(continued)

sites could be purchased. Specifically, the SOT program [illegible] continue through FY 1990. [illegible] program would be [illegible] by 52 missiles so that [illegible] would be able to [illegible] missile before becoming operational. [illegible] (PEAP) would be [illegible] the Trident II program.[illegible]

Finally, if the Trident II program were canceled, the United States would not be able to provide Trident II missiles to the United Kingdom, which is beginning construction of the first of four submarines designed to accommodate 16 Trident II missiles each. Consequently, the United Kingdom would have to modify plans for the submarines so that they could carry Trident I [illegible] Trident II missiles.16

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16. The Trident program provides [illegible] missiles are being [illegible]. [illegible] Missiles are likely to [illegible] of the production. [illegible] the Navy regularly removes a deployed missile [illegible] for signs of deterioration. These missiles [illegible]. Following ground-based inspections [illegible] missiles are [illegible] and are incorporated into [illegible] the spare inventory [illegible] undergoes a major [illegible] the spare inventory following inspections [illegible].

APPENDIX A

METHOD USED TO CALCULATE SSKP

The probability that a warhead will destroy a target is a function of reliability (the probability that the warhead will arrive at the target and detonate) and the Single Shot Kill Probability (SSKP--the probability that the arriving warhead will destroy the target). The SSKP of a warhead depends on the hardness of a target and on the warhead's yield and accuracy. Yield affects the SSKP because a weapon of higher yield produces, at any given radius from the blast, a higher peak overpressure (pressure above standard atmospheric pressure) and a longer period of high overpressures. Both a higher peak overpressure and a longer period of high overpressures increase the probability that a structure will suffer major structural damage from a blast. Better accuracy reduces the distance between the target and the blast.

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Public statements by the Department of Defense on the hardness of targets, however, are given in terms of pounds per square inch (psi) of peak overpressure rather than in terms of a V number. The hardness (H) in pounds per square inch can be converted to a V number with the following formula: [1]

$$V = (5.485 \times \ln(H)) + 4.08$$

---

[1] **This formula can be derived by inserting yield (Y=1,000 kt) and the k-factor (k=7) into the following set of formulas:**

1) $a = 1 - .1k$
2) $b = .1k \times (20/Y)^{1/3}$

(continued)

This formula is based on the assumption that although the V number uses a reference yield of 20 kt, a reference yield of one megaton has been used for estimates of the hardness of Soviet silos measured in pounds per square inch. 2/ The formula is also based on the assumption that structures such as Soviet silos have a sensitivity to the duration of the period of high overpressures, as measured by an index called the "k-factor," of 7. 3/ A formula based on alternative assumptions can be derived from the set of formulas given in footnote 1. With the appropriate V number and k-factor, the probability that a weapon would destroy a target (that is, cause major structural damage) was calculated by using Continuous Read Only Memory (CROM) software developed by DNA. 4/ The CROM software was used in this study because it compensates for the duration of the period of high overpressure, allows calculations at high levels of target hardness such as 5,000 psi, and can be programmed to perform multiple calculations. Comparable results can also be obtained by using a circular slide rule (the "Damage Prediction Rule") developed and distributed by DNA.

There are several alternatives to the DNA CROM software and slide rule for calculating SSKP values. A circular slide rule is manufactured by the Rand Corporation titled the "Bomb Damage Effect Computer." It can calculate SSKP values for targets up to a hardness of 1,000 psi. Two formulas also have been developed to calculate SSKP values. 5/ In these formu-

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1. (continued)

3) $R = a + (b^2/2) + .5((2a + b^2)^2 - 4a^2)^{.5}$
4) $V' = (5.485 \times \ln(H)) - .63$
5) $V = V' - (5.485 \times \ln(R))$

See Maurice Mizrahi, "Appendix A: Hard-Target-Kill Methodology (Unclassified)," *Mobile Missile Mix* (Center for Naval Analysis, Study 1170, vol. 3, April 1982).

2. Information provided by the Defense Nuclear Agency.

3. The k-factor for hardened underground structures such as Soviet ICBM silos normally is between 7 and 8 (Defense Nuclear Agency).

4. Defense Nuclear Agency, *Nuclear Weapons Targeting, AP-550, CROM AI,* Report Number HTI-R-79-110, June 1, 1979 (Unclassified).

5. Both formulas are presented in detail in Lynn Davis and Warner Schilling, "All You Ever Wanted To Know About MIRV and ICBM Calculations But Were Not Cleared To Ask," *Journal of Conflict Resolution*, vol. XVII, no. 2 (June 1973). Given the assumptions made in this study (k-factor of 7 and reference yield of one megaton), these formulas give comparable results to the CROM A1 software when warhead yield is 100 kt. At significantly lower or higher yields, results can diverge substantially.

las, "Y" is the yield measured in megatons; "H" is the hardness of the target measured in pounds per square inch (psi); and "CEP" is the accuracy measured in nautical miles by the Circular Error Probable--the radius of a circle around a target such that there is a 50 percent probability that the warhead aimed at the target will detonate within or above the circle.

1) $SSKP = 1 - .5^{A}$ where $A = \dfrac{6Y^{2/3}}{H^{2/3}CEP^{2}}$

2) $SSKP = 1 - .5^{A}$ where $A = \dfrac{8.41Y^{2/3}}{H^{.7}CEP^{2}}$

The SSKP calculated using these different approaches can, under some assumptions, vary by 10 percent to 15 percent. Such variations should not be a major cause for concern, however, when placed in the context of uncertainty about other assumptions including weapon reliability, the yield and accuracy of warheads, the overpressure required to crush or deform particular structures, and the probability that a facility would be disabled by effects other than major structural damage.

[illegible] vulnerability, as measured by an index called the "SSKP," [illegible] formula based on alternative assumptions can be derived from [illegible] formulas given in footnote [illegible] the probability that a [illegible] would destroy a target [illegible] damage was calculated by using Continuous [illegible] (CDCP) software developed by DIA. The [illegible] software was used in this study because it [illegible] high levels of target hardness such as 5,000 psi, and can be programmed to perform [illegible] calculations. Comparable results can also be obtained by using a [illegible] slide rule [illegible]

[illegible] has also been developed [illegible]

[illegible]

See [illegible] "Appendix A: [illegible]," [illegible] Center for Naval Analyses [illegible] April 1980.

[illegible] provided by the Defense Nuclear Agency.

[illegible] Defense Nuclear Agency.

[illegible] (Unclassified).

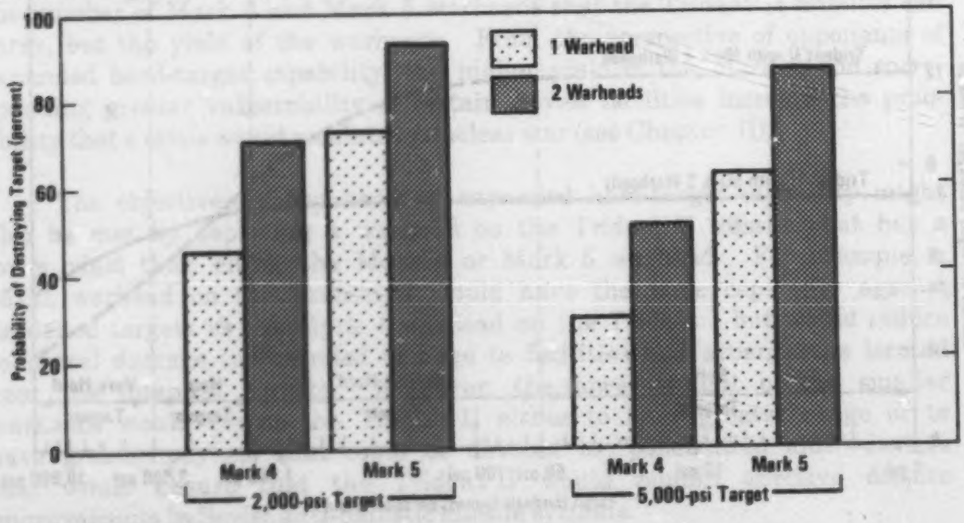
Both formulas are presented in detail in Lynn Davis and Warner Schilling, [illegible] *Journal of Conflict Resolution*, vol. XVII, no. 2 (June 1973). [illegible] assumptions made in this study. [illegible]

APPENDIX B

THE CHOICE OF TRIDENT II WARHEADS

This study assumes that 50 percent of the Trident II missiles would be deployed with the Mark 4 warhead and 50 percent with the Mark 5. This ratio affects the capability of the Trident II missile force. Although the Trident II can carry fewer Mark 5 warheads (six to nine) than Mark 4 warheads (11 to 13), the yield of the Mark 5 (400-500 kt) is higher than the yield of the Mark 4 (100 kt). The higher yield of the Mark 5 gives it a higher Single Shot Kill Probability (SSKP--the probability that an arriving warhead will destroy a target) than the Mark 4. One Mark 5 warhead, for example, has a higher probability than two Mark 4 warheads of destroying a target hardened to 2,000 or 5,000 pounds per square inch (psi) (see Figure B-1).

Figure B-1.
Effectiveness of Mark 4 and Mark 5 Warheads on the Trident II Missile Against Targets Hardened to 2,000 psi and 5,000 psi



SOURCE: Congressional Budget Office.

NOTE: Effectiveness is measured here by the probability that either one or two warheads will destroy a hardened target. That probability, known as the probability of kill (PK), is based on the Single Shot Kill Probability (SSKP) for each warhead type against a target of specified hardness and on the reliability (R) of 80 percent. The calculations employ the following equation, in which "N" is the number of warheads directed at the target:

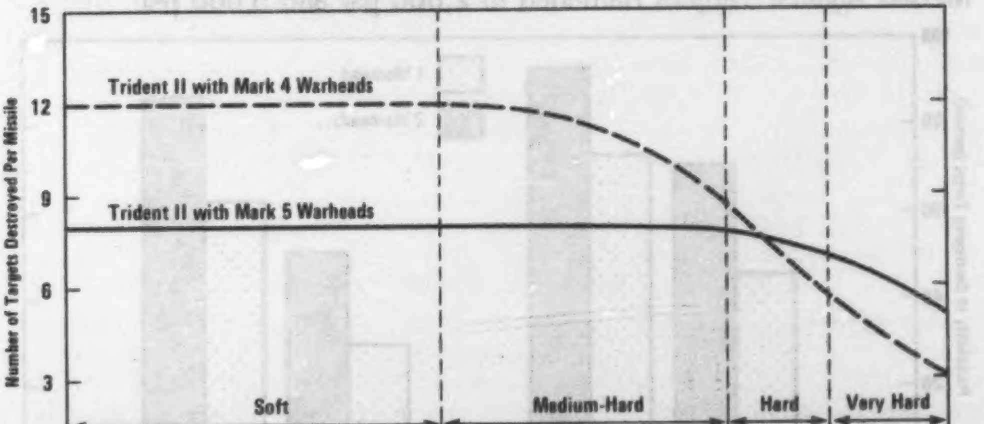
$$PK = 1 - [1 - (SSKP \times R)]^N$$

Therefore, there is a trade-off between the number of warheads and the capability of the individual warheads. Against "soft" targets hardened to less than 50 psi--a situation in which the difference in yield between the Mark 4 and Mark 5 warheads has little effect on the SSKP--the Trident II missile with Mark 4 warheads could attack and destroy more soft targets than with Mark 5 warheads (see Figure B-2). Against targets hardened to greater than about 1,600 psi, however, the Trident II missile with Mark 5 warheads would be more effective. Because of the higher SSKP of the Mark 5 warhead against harder targets, a Trident II missile would destroy more targets with fewer Mark 5 warheads than with a larger number of Mark 4 warheads (see Figure B-2).

For attacking targets hardened to an intermediate range of between 50 psi and 1,600 psi, however, the relative effectiveness of Mark 4 and Mark 5 warheads is less clear. The Trident II with Mark 4 warheads is more effective if each warhead is directed against a separate target. But, if some Mark 4 warheads are not used because there are more warheads

Figure B-2.

Capability of a Single Trident II Missile as a Function of Warhead Type and Target Hardness



SOURCE: Congressional Budget Office.

NOTE: The Trident II could carry 11 to 13 Mark 4 warheads or 6 to 9 Mark 5 warheads. For the purpose of illustration, it is assumed that the missile would carry 12 Mark 4 warheads or 8 Mark 5 warheads.

than targets within the footprint of the missile (the area over which a single missile can distribute its warheads), then the Trident II equipped with Mark 5 warheads might be more effective.

The relationship between the number of warheads and their yield has implications for both proponents and opponents of expanded hard-target capability. Proponents would want to ensure that the percentage of Trident II missiles equipped with Mark 4 and Mark 5 warheads would result in the maximum capability and flexibility against the set of hardened targets in the Soviet Union. The optimal mix of warheads is difficult to determine, however, without detailed analysis of the U.S. Strategic Integrated Operational Plan (SIOP)--the nation's blueprint for conducting strategic nuclear war. Since this plan is classified, determining the optimal mix probably must be left to the Joint Strategic Target Planning Staff and the Department of Defense.

For opponents of expanded hard-target capability, the issue is the degree to which selecting one warhead rather than the other might minimize the destabilizing effects of deploying the Trident II missile. To achieve this objective, the case is strongest for deploying only the Mark 4 warhead. Whether only the Mark 4 or only the Mark 5 were deployed, the United States would have enough prompt hard-target warheads on SLBMs to employ at least two such warheads against as many as 1,800 to 1,900 of the most important Soviet installations. Therefore, the most relevant factor is not the number of Mark 4 and Mark 5 warheads that the Trident II missiles can carry, but the yield of the warheads. From the perspective of opponents of expanded hard-target capability, the higher yield of the Mark 5 and corresponding greater vulnerability of certain Soviet facilities increase the probability that a crisis would escalate to nuclear war (see Chapter II).

The objectives of opponents of expanded hard-target capability might also be met by deploying a warhead on the Trident II missile that has a lower yield than either the Mark 4 or Mark 5 warhead. For example, a 25-kt warhead on the Trident II would have the same capability against hardened targets as the Mark 4 warhead on the Trident I but would reduce collateral damage (unintended damage to facilities and urban areas located near the intended target). Moreover, the lower weight of the smaller warheads would enable the Trident II either to have greater range or to have greater payload that could be devoted to "penetration aids"--devices that would ensure that the Trident II would remain effective despite improvements in Soviet anti-ballistic missile systems.

than targets within the footprint of the missile; an area over which a single Trident can attack with its warheads, other Trident II equipped with Mark 4 warheads might be unaffected while [illegible]

The relationship between the number of warheads and their yield has implications for both proponents and opponents of expanded hard-target capabilities. Proponents would want to ensure that the preponderance of Trident II missiles equipped with Mark 4 and Mark 5 warheads would result in the greatest capability and flexibility against the hardened targets in the Soviet Union. The optimal mix of warheads is difficult to determine, however, without detailed analysis of the U.S. Strategic Integrated Operational Plan (SIOP)—the nation's blueprint for conducting strategic nuclear war. Since this plan is classified, determining the optimal mix probably must be left to the Joint Strategic Target Planning Staff and the Department of Defense.

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The objectives of opponents of expanded hard-target capability might also be met by developing a warhead for the Trident II missile that has a lower yield than either the Mark 4 or Mark 5 warhead. For example, a 25-kt warhead on the Trident II would have the same capability against hardened targets as the Mark 4 warhead on the Trident I but would reduce collateral damage (unintended damage to facilities and urban areas located near the intended target). Moreover, the lower weight of the smaller warheads would enable the Trident II either to have greater range or to have greater payload that could be devoted to penetration aids—devices that would ensure that the Trident II would remain effective despite improvements in Soviet anti-ballistic missile systems.

[illegible]

APPENDIX C

PERFORMANCE OF U.S. BALLISTIC MISSILES AGAINST TARGET SETS HARDENED TO 5,000 PSI

In the text of this report, the performance of U.S. ICBMs and SLBMs was evaluated against target sets hardened to both 2,000 and 5,000 pounds per square inch (psi). To simplify presentation and to facilitate comparison of the performance of U.S. ICBMs and SLBMs under the Administration's plan and alternatives to that plan, however, Figures 13 through 15 in the text presented the performance of U.S. ballistic missiles only against target sets hardened to 2,000 psi. Figures C-1, C-2, and C-3 (overleaf) are the same figures except that they present performance against target sets hardened to 5,000 psi.

Figure C-1.

Administration's Plan and Alternatives: Performance of U.S. ICBMs and SLBMs Against a Large Target Set, Fiscal Years 1985-2000

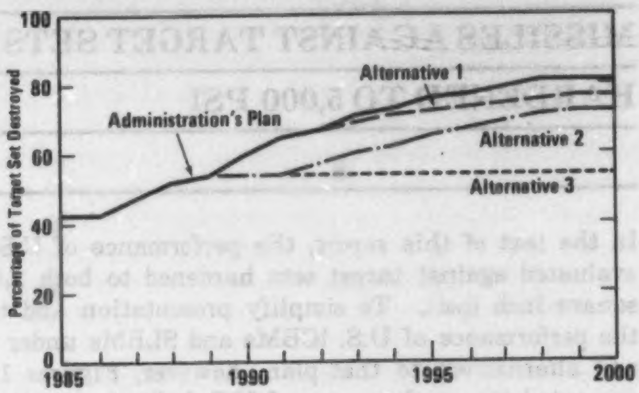


Figure C-2.

Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Large Target Set, Fiscal Years 1985-2000

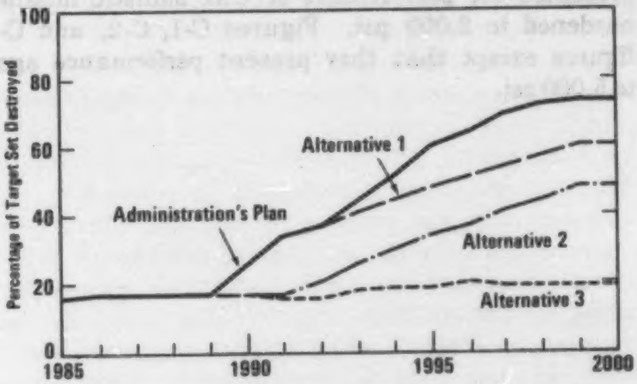
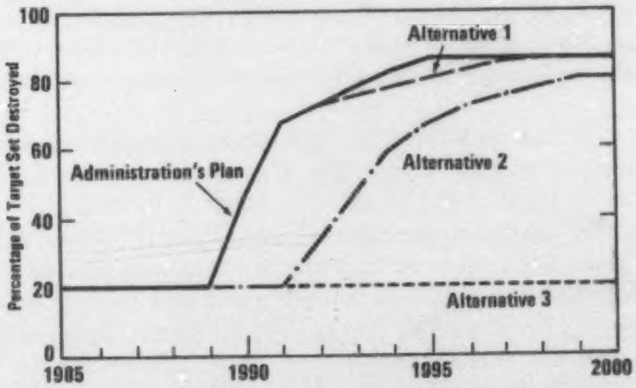


Figure C-3.

Administration's Plan and Alternatives: Performance of U.S. SLBMs Against a Small Target Set, Fiscal Years 1985-2000



SOURCE: Congressional Budget Office.

NOTES: A large target set (Figures C-1 and C-2) is 2,000 facilities; a small target set (Figure C-3) is 500 facilities. All three figures illustrate the performance of ballistic missiles against target sets hardened to 5,000 psi. The calculations are based on the assumptions that no more than two warheads are allocated against any one target and that the reliability of SLBMs is 80 percent. U.S. warheads are allocated to maximize the percentage of targets destroyed. Alternative 1 = Cancel Backfits; Alternative 2 = Delay Procurement of Trident II Missiles; Alternative 3 = Cancel Trident II Program.

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